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THESIS

AN ANALYSIS OF A PC-3 MICROPULSATION IN THE GEOMAGNETIC FIELD

by

Kurt B. Stevens

June 1983

Thesis Adivsor: A. Ochadlick

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To isolate data containing a micropulsation event, time series plots of the magnetic field were generated. The

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Power spectral density (PSD) plots summarizing data segments about two hours long occasionally contained structures found to be artificial and not representative of natural phenomena in the geomagnetic field. Methods to avoid this anomalous behavior in PSD plots are suggested.

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An Analysis of a PC-3 Micropulsation in the Geomagnetic Field

by

Kurt B. Stevens
Captain, United States Air Force
B.S., United States Air Force Academy, 1979

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requirements for the degree of

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I. INTRODUCTION

This thesis is part of an ongoing effort at the Naval Postgraduate School to analyze ULF geomagnetic noise and micropulsations. The results of the Naval Postgraduate School studies could impact communications systems or systems in which geomagnetic noise and/or micropulsations introduce operational difficulties.

An objective of this thesis was to develop the software necessary for obtaining computer generated plots of geomagnetic field versus time. Then, with the plots, sections of data containing obvious geomagnetic micropulsations were located. Those sections were analyzed to determine the power spectral density (PSD), coherence, degree of polarization and ellipticity of the micropulsation using already developed software [Ref. 1].

After analyzing some of the plots (PSD, coherence, etc.) produced by the software documented in [Ref. 1], it was demonstrated that problems existed in the software. New software was developed to obtain times series raw voltage and geomagnetic field plots. Validation of the software required an on-site experiment. Documented within this thesis is the software to produce time series voltage and geomagnetic field plots and the questions the validation experiment raised concerning the sensing system and software.

Using the newly developed software, a micropulsation event was located. A double running average software routine accentuated the micropulsation to permit the determination of its frequency and amplitude. The micropulsation event was further analyzed to obtain information on coherence, degree of polarization and ellipticity.

II. BACKGROUND

A. COLLECTION SYSTEM

The Naval Postgraduate School has two operating geomagnetic sensing systems. The land site is located at the La Mesa Village Housing Area and has three orthogonally mounted induction coils. The second operating system contains two orthogonally mounted induction coils that can be placed on the bottom of Monterey Bay. When both systems are operating, the data is collected simultaneously. The ground work has been laid for a third system located at Chew's Ridge. Three orthogonal and simultaneous measurements can be taken only between two sites since the School has only five induction coils and a sixth just calibrated. This thesis used data from the La Mesa Village site and the software associated with it.

An induction coil senses the geomagnetic field fluctuations based on Faraday's Law of induction, induced emf $= -N\frac{d\Phi}{dt}$, which describes the relation between the induced emf and the time rate of change of magnetic flux through the coil. N is the number of turns in the coil.

The voltage induced in the coils is sampled 32 or 64 times/second and is amplified approximately one million times. The voltage data undergoes pulse-code-modulation (PCM) for noiseless VHF radio link transmission from the La Mesa Village site, to the recording system in the Geophysics Signal

Processing Laboratory located in Spanagel 531. Data reduction on the Naval Postgraduate School's IBM 3033 computer follows digitization of the PCM data. A block diagram of the system is provided in Figure 2.1. A more detailed description of the system is given in Reference 2.

1. System Calibration

For purposes of documentation, the calibration of the third coil for either the Chew's Ridge or Monterey Bay system is being included in this thesis. The general method of induction coil calibration will be covered here. For a more indepth explanation, see Reference 1.

The sensing coil and its associated electronics are calibrated using a Helmholtz coil apparatus to establish a uniform magnetic field. By placing the sensing coil into the field produced by the Helmholtz coil, one can establish a relationship between the Helmholtz coil magnetic field magnitude and frequency and the coil system voltage. Once the response of the coil system is known for the frequency band of interest, it can be included in the system transfer function used in data reduction.

The experiment to determine the sixth coil system transfer function was done at the La Mesa Village site. A Wavetek Model 142 signal generator supplied a sinusoidal current to a 1.22 meter diameter, 0.61 meter high Helmholtz coil. The current was measured across a 996 ohm resistor in series with the Helmholtz coil. A Hewlett Packard HP-3582A spectrum

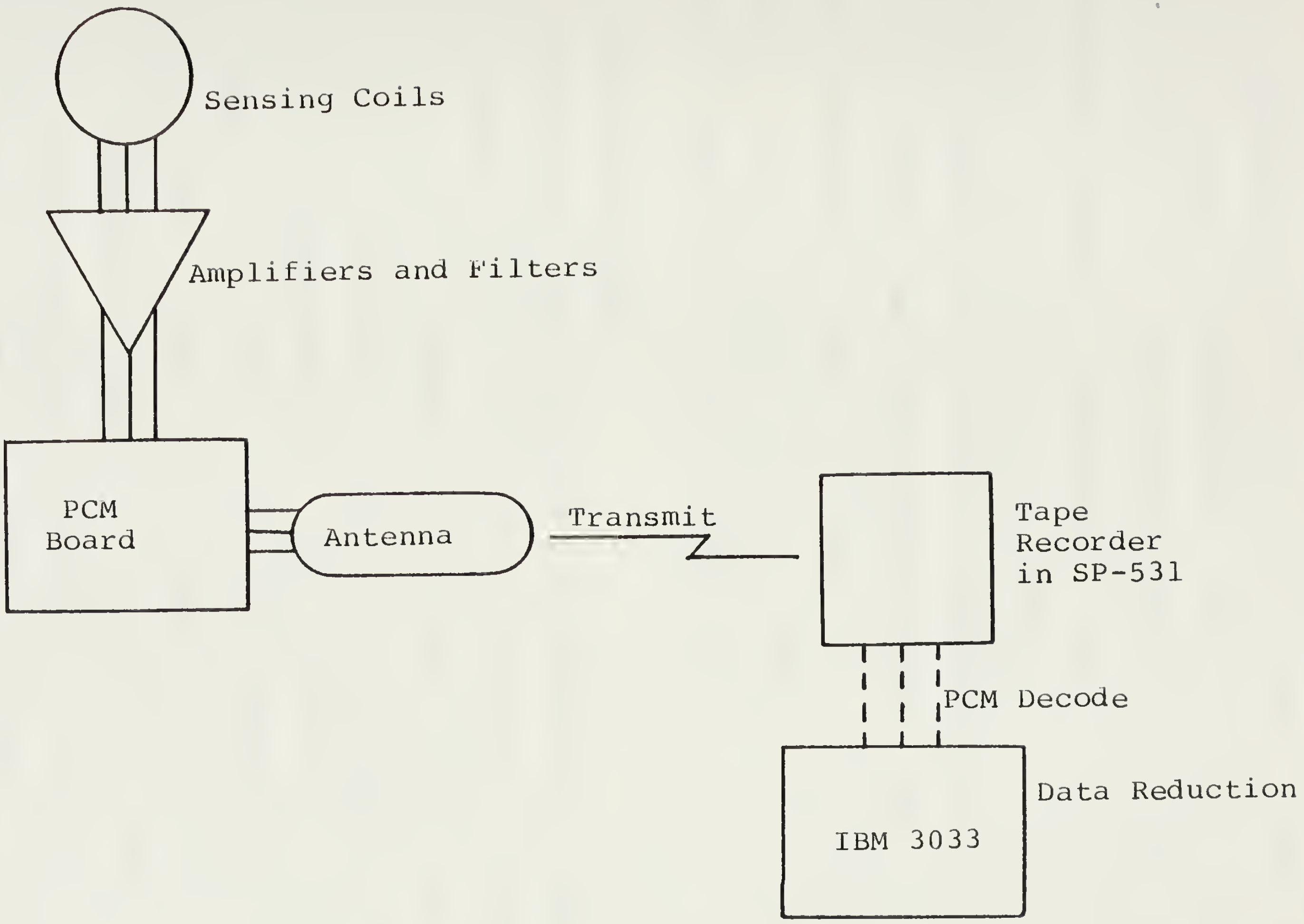

Figure 2.1. System Data Flow

analyzer measured the output voltage of the coil system as a function of frequency.

The experiment measured the response of the coil system in the frequency band .05 hertz to 20 hertz for applied fields of 0.02, 0.2 and 1.0 nanoteslas. The coil system response is shown in Figure 2.2. The transfer function of this coil system corresponds closely to those of coil systems previously calibrated. The only noticable difference is that the 0.02 nanotesla response at 15 hertz is approximately 15 volts/ nanotesla higher than those measured before [Ref. 1]. It should be noted that this difference will not influence data analysis in the frequency range of interest. The transfer function algorithm is listed in Table 2.1.

B. PREVIOUS SOFTWARE

Software has been developed (see References 1 and 3), to extract power spectral densities for each coil, coherence between the coils, degree of polarization in the three measurement planes, ellipticity in the three measurement planes and a variety of Stokes parameters. The following is a basic description of the computer code that produces the above mentioned plots. First, the voltage data is read off the digital tape using a subroutine called RD provided by Dr. Tim Stanton of the Oceanography Department. A parameter ISEC, representing the number of seconds one wishes to advance the tape, is frequently used. ISEC establishes the number of

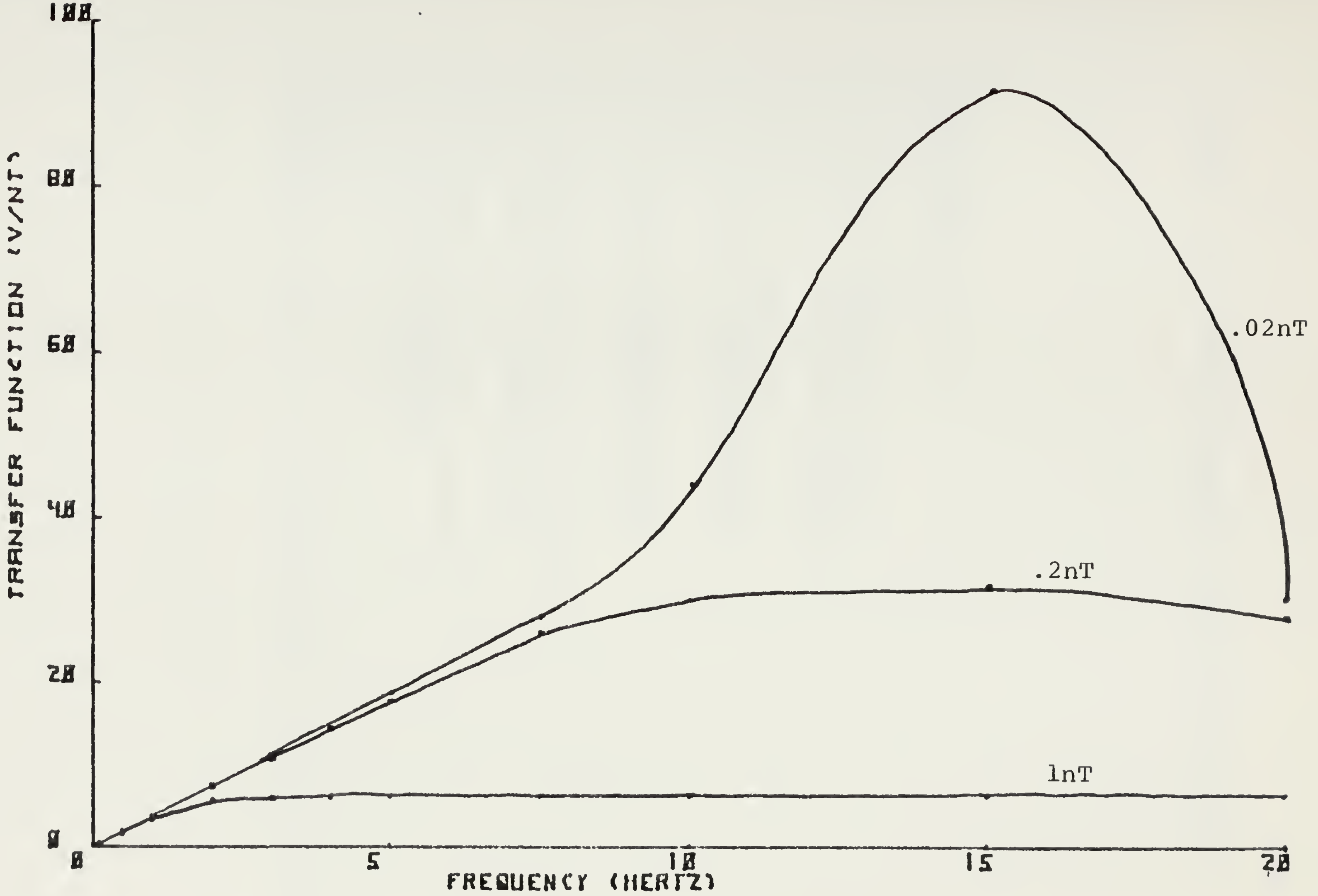

Figure 2.2. Coil Transfer Function

Table 2.1. System Transfer Function Algorithm

```
      DO 9 L=1,N
      FRQ=FREQ(L)
      IF(FRQ.LE.25.)GO TO 1
      XX(L)=XX(L)/28.
      GO TO 8
    1 IF(FRQ.LE.15.)GO TO 2
      XX(L)=XX(L)/(105.5-3.14*FRQ)
      YY(L)=YY(L)/(181.32-7.588*FRQ)
      ZZ(L)=ZZ(L)/(177.26-7.484*FRQ)
      GO TO 8
    2 IF(FRQ.LE.10.)GO TO 3
      XX(L)=XX(L)/(5.958*FRQ-30.97)
      YY(L)=YY(L)/(7.166*FRQ-39.99)
      ZZ(L)=ZZ(L)/(6.49*FRQ-32.35)
      GO TO 8
    3 IF(FRQ.LE.7.5)GO TO 4
      XX(L)=XX(L)/(3.492*FRQ-6.31)
      YY(L)=YY(L)/(4.252*FRQ-10.85)
      ZZ(L)=ZZ(L)/(4.044*FRQ-7.89)
      GO TO 8
    4 IF(FRQ.LE.5.)GO TO 5
      XX(L)=XX(L)/(2.6311*FRQ+0.14667)
      YY(L)=YY(L)/(3.012*FRQ-1.55)
      ZZ(L)=ZZ(L)/(3.184*FRQ-1.44)
      GO TO 8
    5 IF(FRQ.LE.3.)GO TO 6
      XX(L)=XX(L)/(2.6311*FRQ+0.14667)
    7 YY(L)=YY(L)/(2.702*FRQ)
      ZZ(L)=ZZ(L)/(2.92*FRQ)
      GO TO 8
    6 XX(L)=XX(L)/(2.72*FRQ)
      GO TO 7
    8 CONTINUE
      TF(L)=(XX(L)*COSD + YY(L)*COSD1)*COS60 + ZZ(L)*COS30
    9 CONTINUE
```

times RD is called and the data not stored. Previously, tape advances of approximately 30 seconds or ISEC = 30 were used. Once the tape is advanced the desired amount, data analysis can begin. Each digital tape contains about 90 minutes or 1.728×10^5 pieces of data per axis resulting from the sampling rate of 32 samples/second. Because of the large amount of data, the analysis has to be accomplished in blocks. Data analysis takes place on 256 seconds or 8192 frames of data at a time. RD is called 8192 times and places the voltages for each coil in an array. The voltages are integer values from 0 to 4096 representing -5 volts to +5 volts. Ideally the value 2048 represents 0 volts. The integers between 0-4096 are normalized to ± 5 volts and placed in new complex arrays. These arrays containing 8192 pieces of data are Fourier transformed to the frequency domain where the system transfer function is applied. After applying the transfer function, the calculations begin for a determination of PSD's, coherence, ellipticity, etc. for the first block. After they are complete, the next block of 8192 pieces of data starts through the program. Once the desired amount of data has been processed, a NONIMSL subroutine called DRAWP plots the data. For a more complete description of this software, see Reference 1, Reference 3 and Reference 4.

C. ANALYSIS OF INITIAL DATA PLOTS

Many of the PSD's, coherences, ellipticities and degree of polarization plots produced by the software of Reference 1 and Reference 3 have unexpected characteristics. The PSD's show "humps" that are shown in Figures 2.3-2.5. These "humps" are not characteristic in "normal" PSD's. The coherence plots show a coherence of essentially one degrading to hash in the frequencies greater than 2 hertz, Figures 2.6-2.8. We see a similar behavior in the plots of degree of polarization. These plots indicate a very highly polarized field from 0.02 hertz to 1.0 hertz. Figures 2.9-2.11. The ellipticity plots show a very linearly polarized field for these frequencies in Figures 2.12-2.14.

After examining the time series magnetic field plots, we noted a section of very large magnitude fluctuations (about one to three orders of magnitude greater than the general background) at the beginning of the digital tapes Figures 2.15-2.17. We found that if the digital tape was advanced past these large fluctuations the output (PSD, coherence, etc.) appeared "normal", Figures 2.18-2.29. If the program was executed on just the section containing the large fluctuations, the PSD's had the "humped" characteristic, the coherences were one, the degree of polarization was very high and the ellipticity was linear, Figures 2.30-2.41. This demonstrates that these large fluctations dominate the output of an analysis in the frequency domain. A tape advance of 300 seconds or ISEC = 300 is

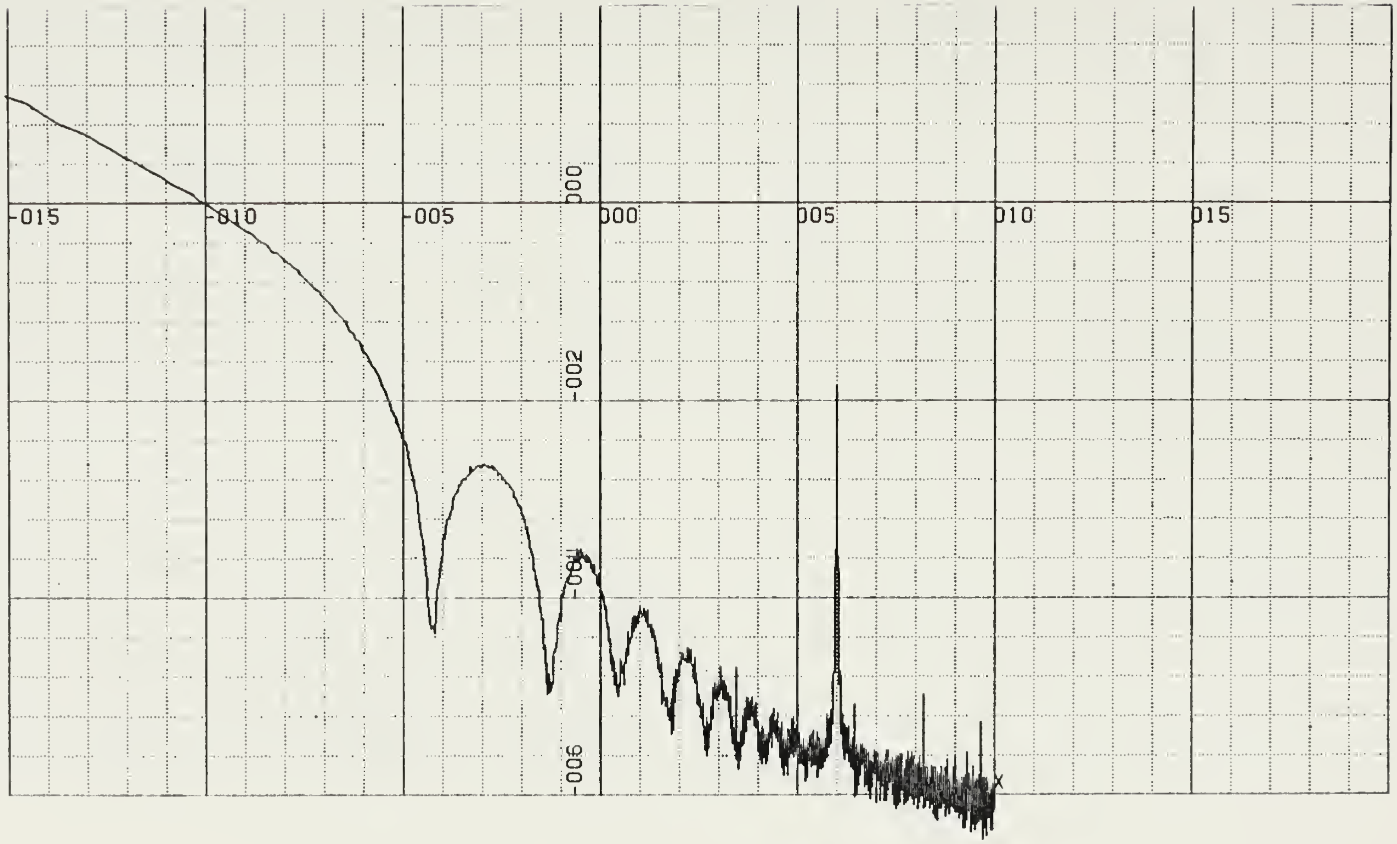

Figure 2.3. PSD X-Coil, 17 August 82, 2240-2348 Local. Amplitude in dB (REF nT**2/Hz) (20 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

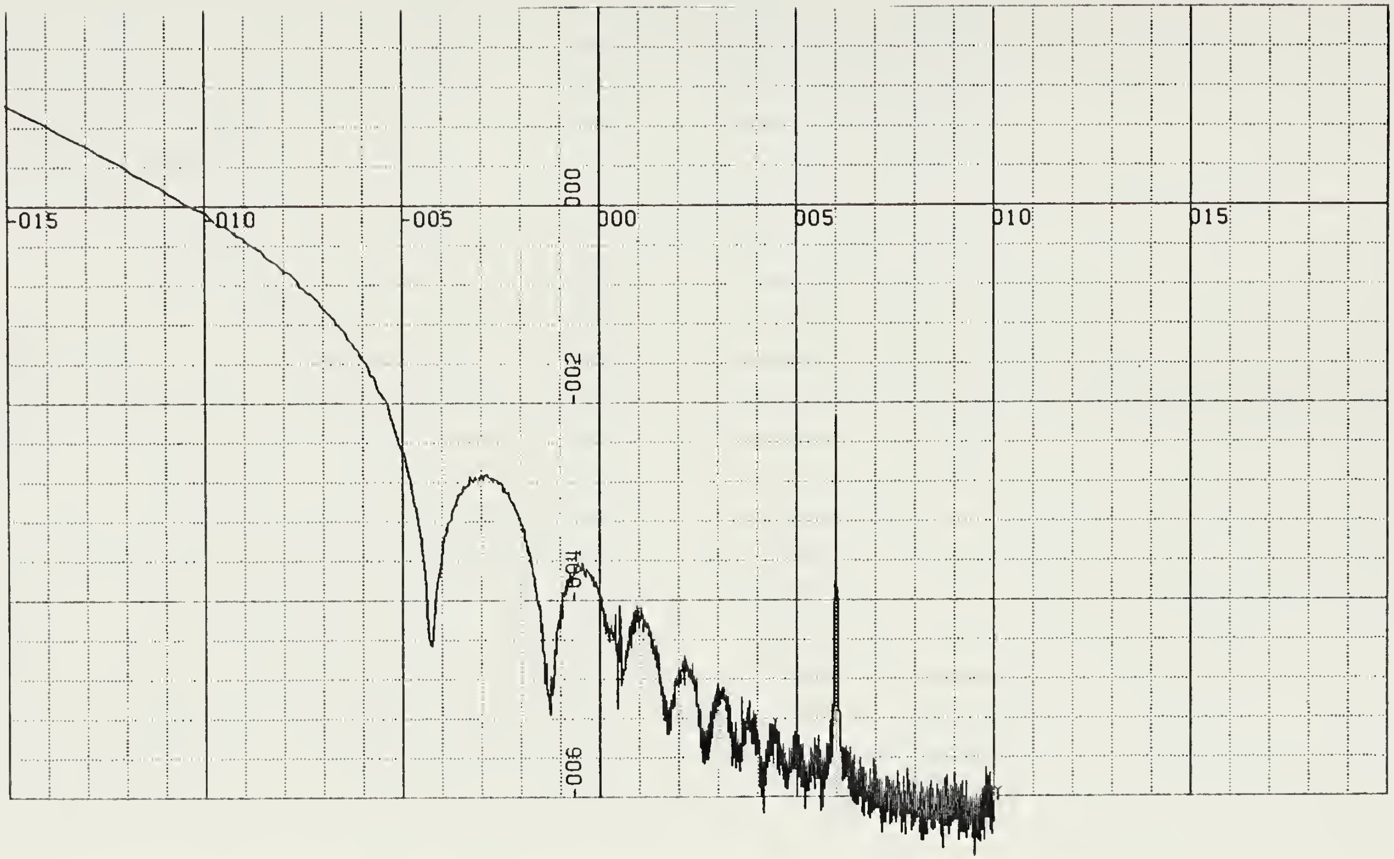

Figure 2.4. PSD Y-Coil, 17 August 82, 2240-2348 Local. Amplitude in dB (REF nT**2/Hz) (20 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

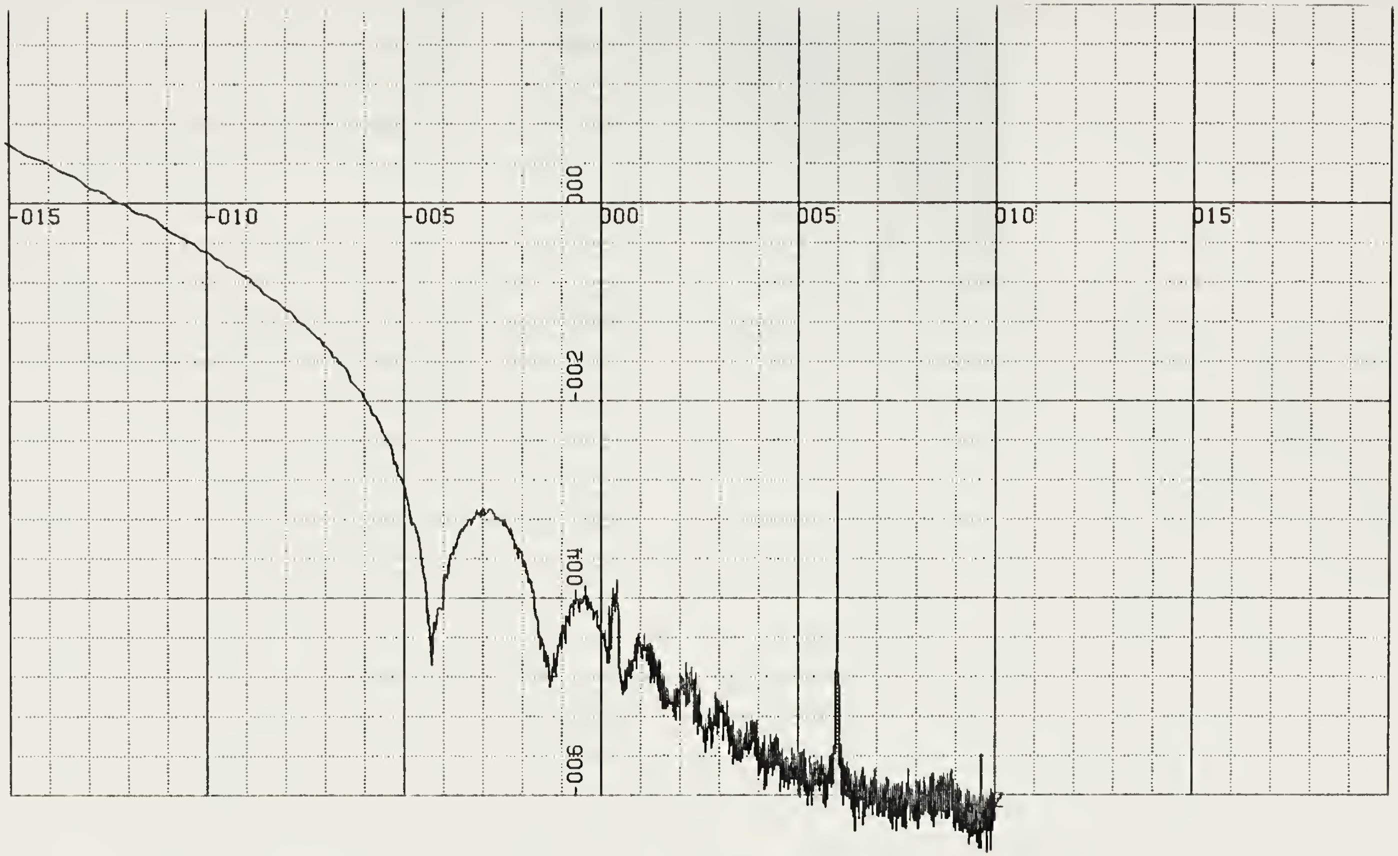

Figure 2.5. PSD Z-Coil, 17 August 82, 2240-2348 Local. Amplitude in dB (REF nT**2/Hz) (20 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

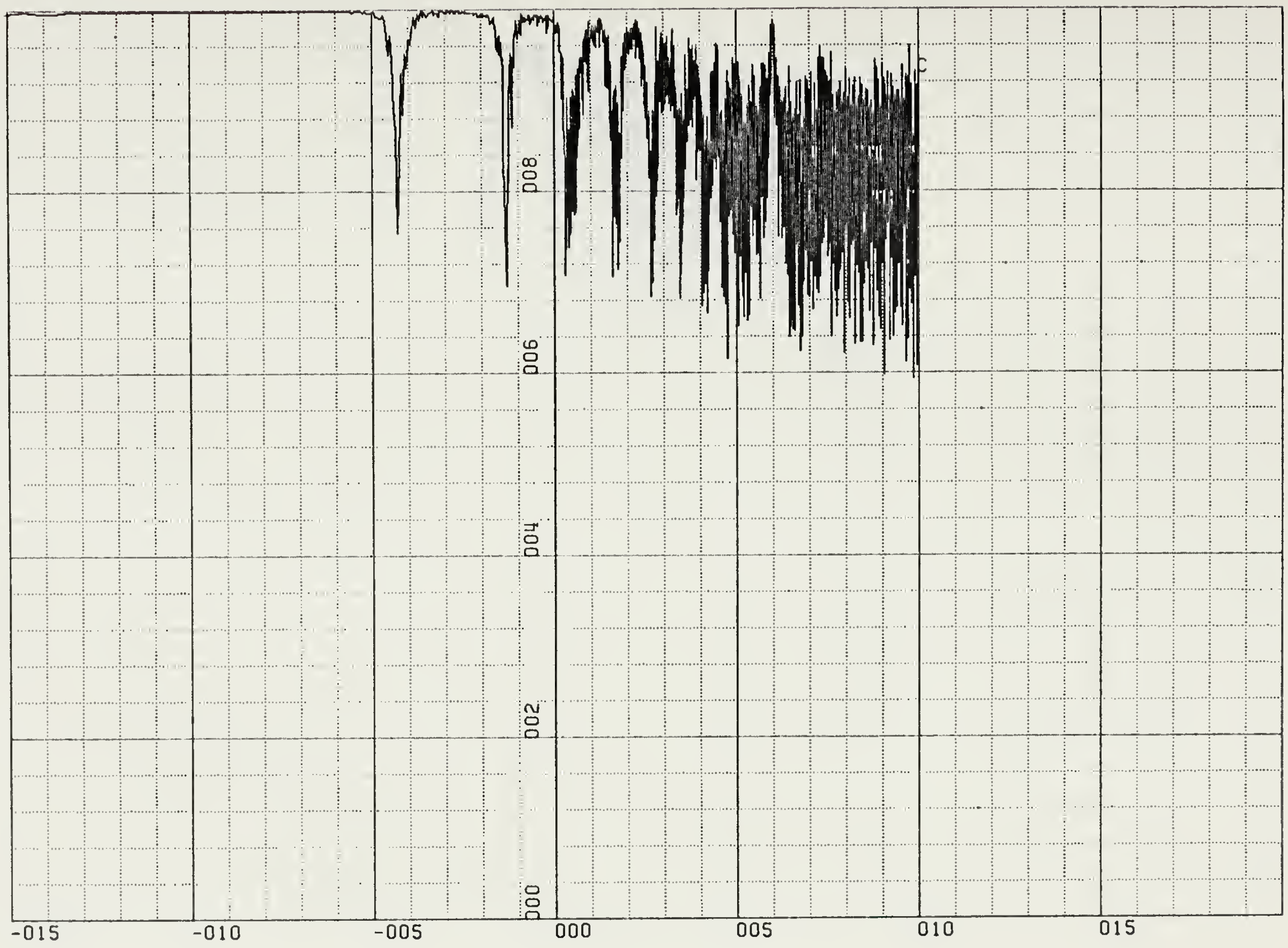

Figure 2.6. Coherence X and Y coils, 17 August 82, 2240-2348 Local. Coherence X and Y Coil (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

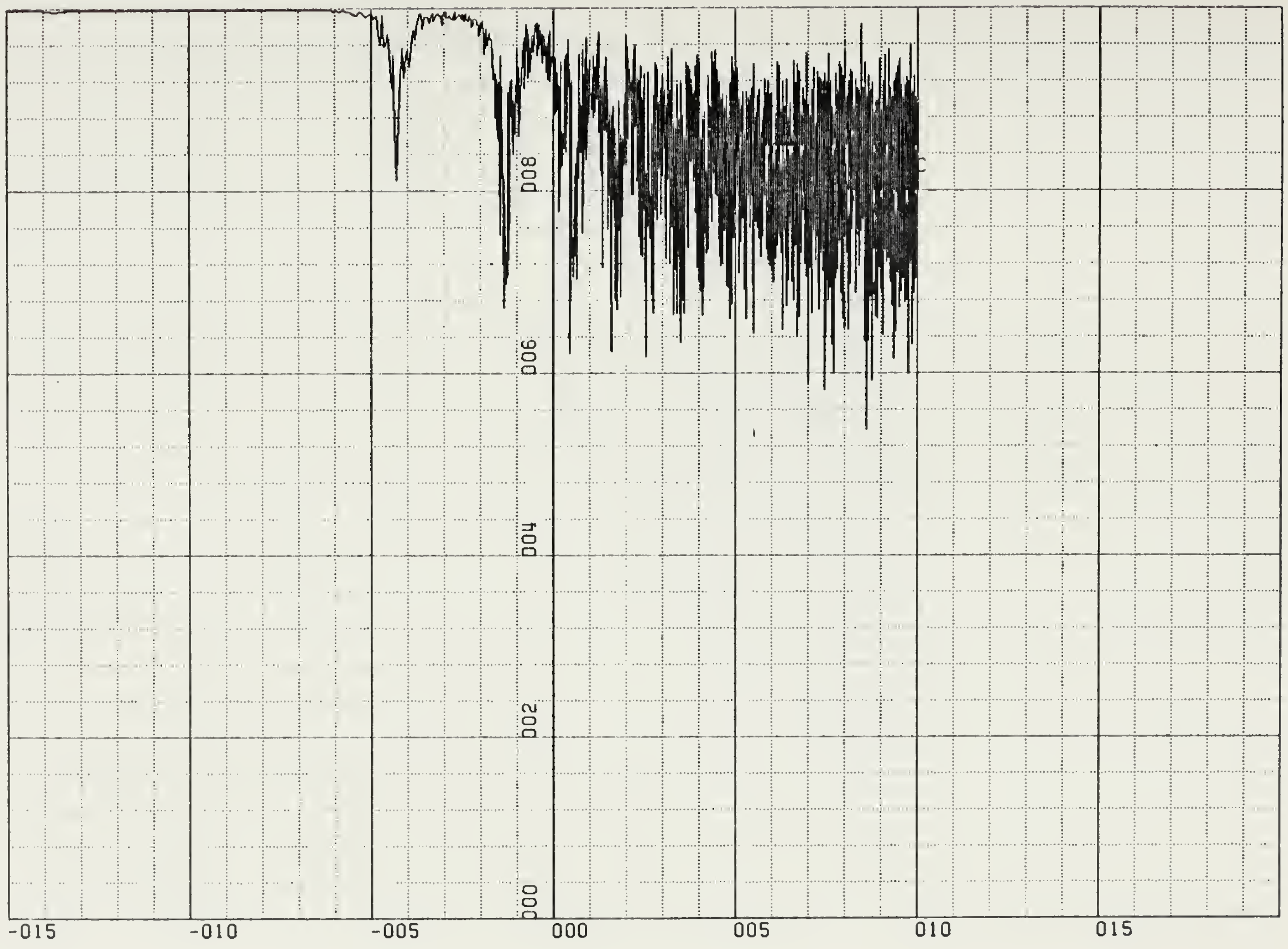

Figure 2.7. Coherence Y and Z Coils, 17 August 82, 2240-2348 Local. Coherence Y and Z Coils (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

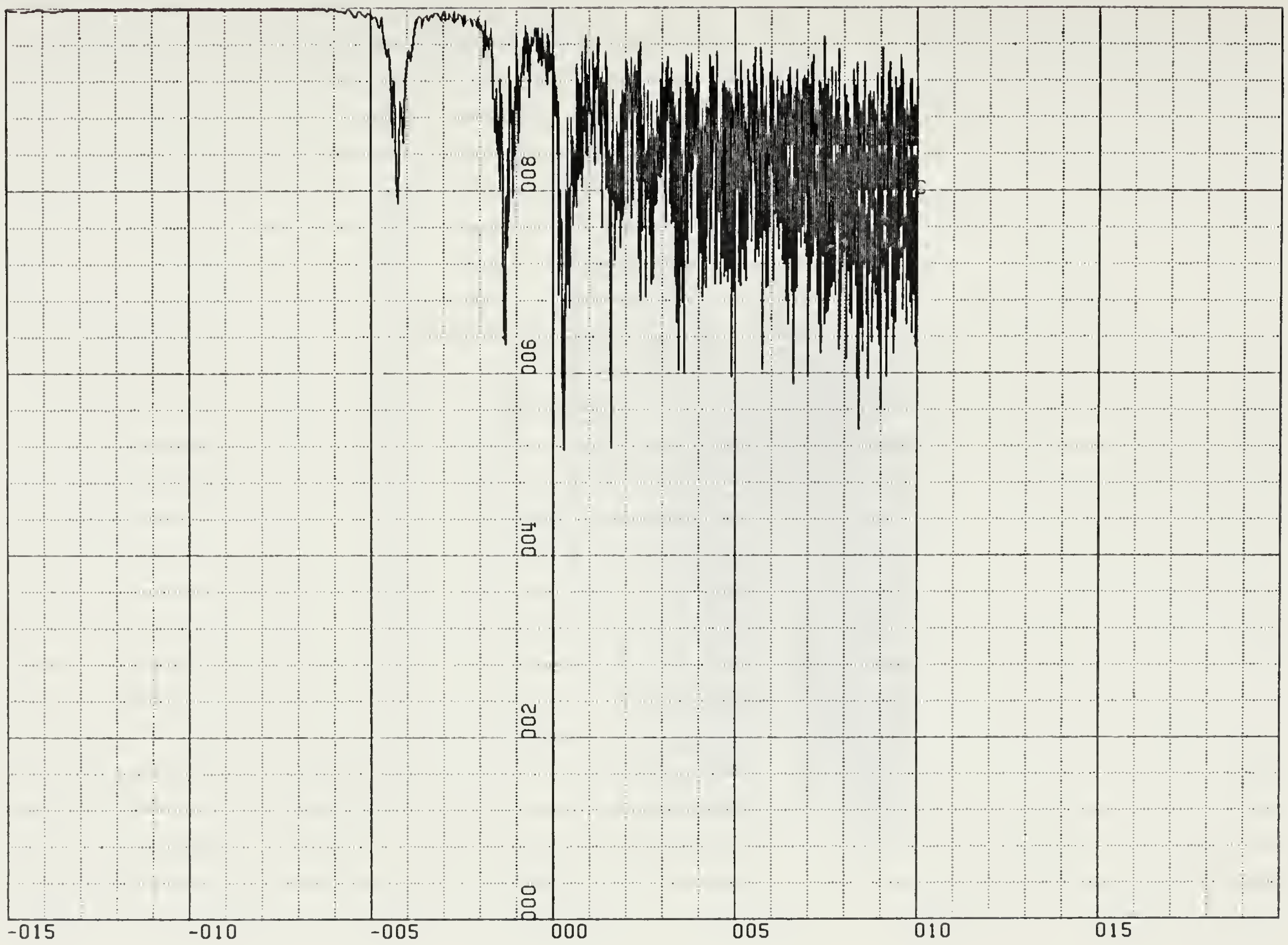

Figure 2.8. Coherence Z and Z Coils, 17 August 82, 2240-2348 Local. Coherence Z and X Coils (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

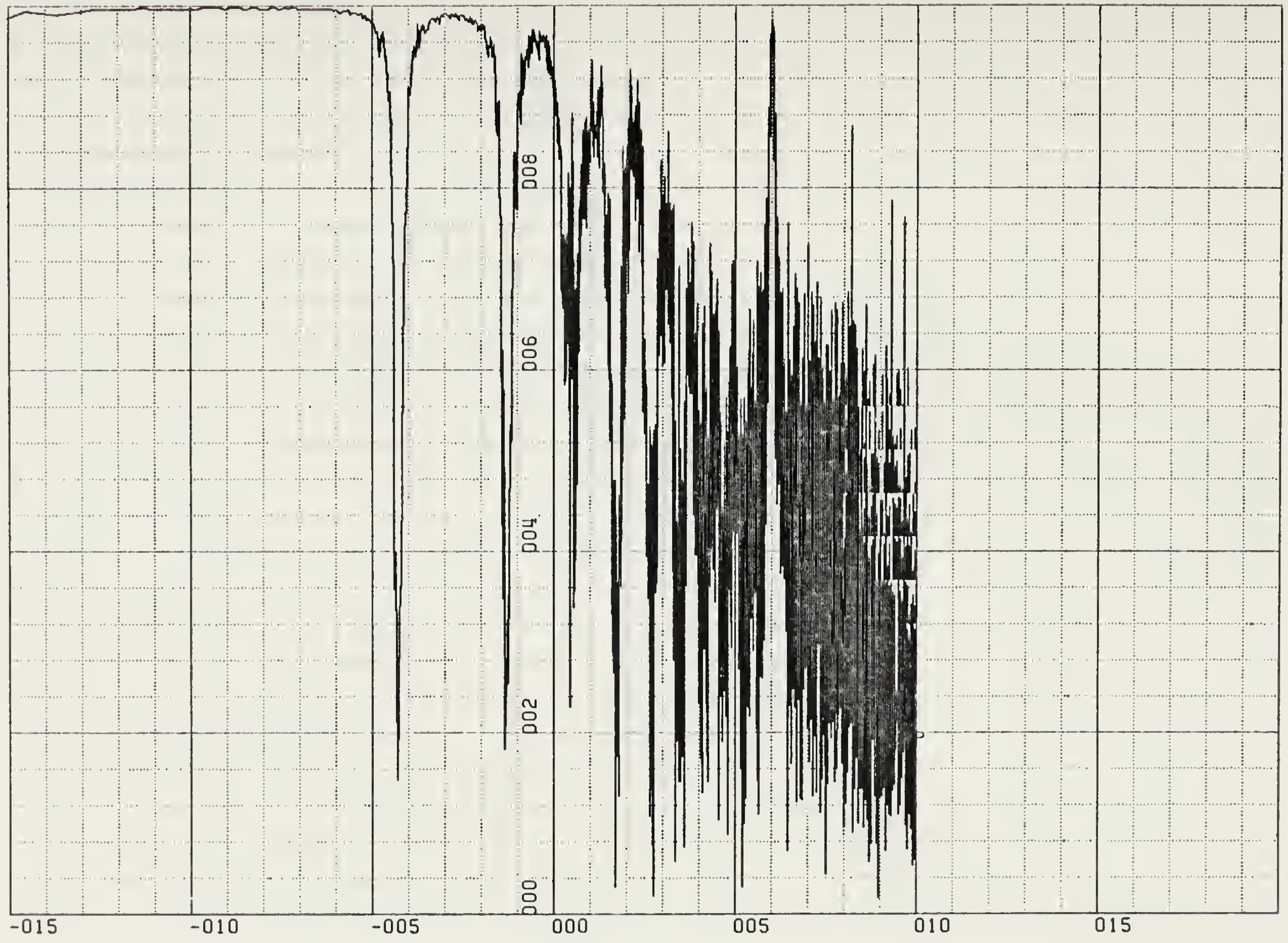

Figure 2.9. Degree of Polarization X-Y Plane, 17 August 82, 2240-2348 Local. Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

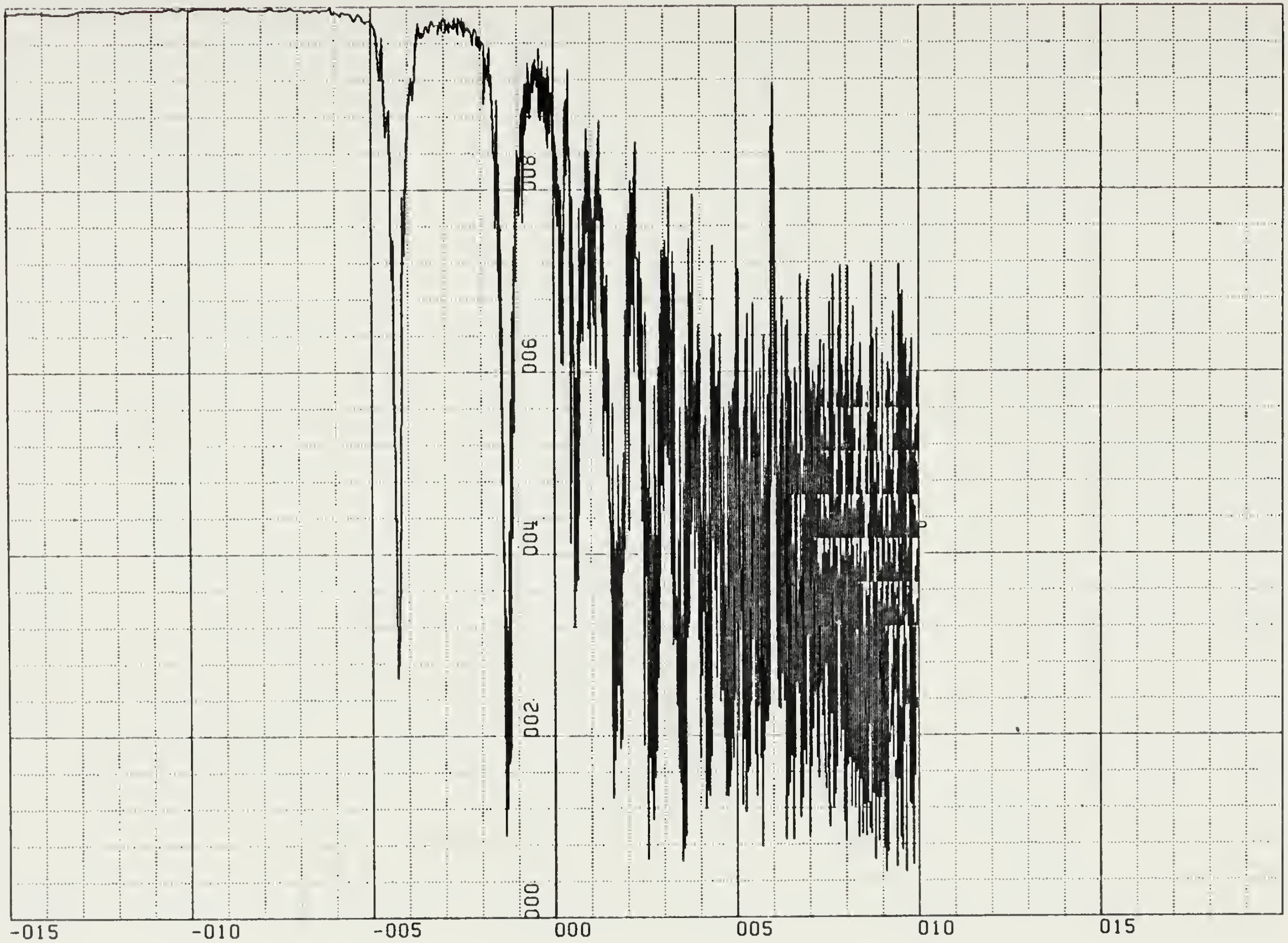

Figure 2.10. Degree of Polarization Y-Z Plane, 17 August 82, 2240-2348 Local. Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

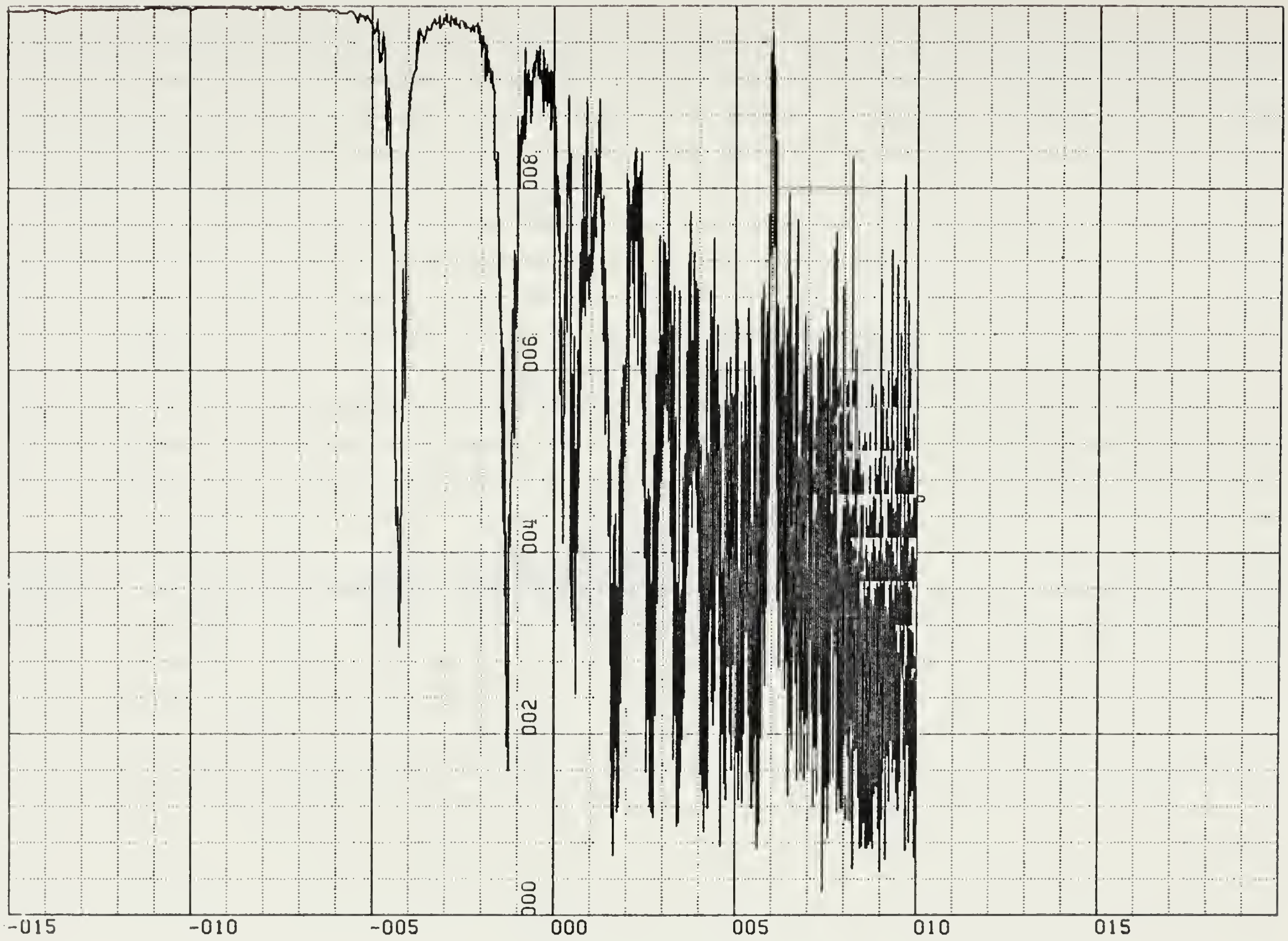

Figure 2.11. Degree of Polarization Z-X Plane, 17 August 82, 2240-2348 Local. Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

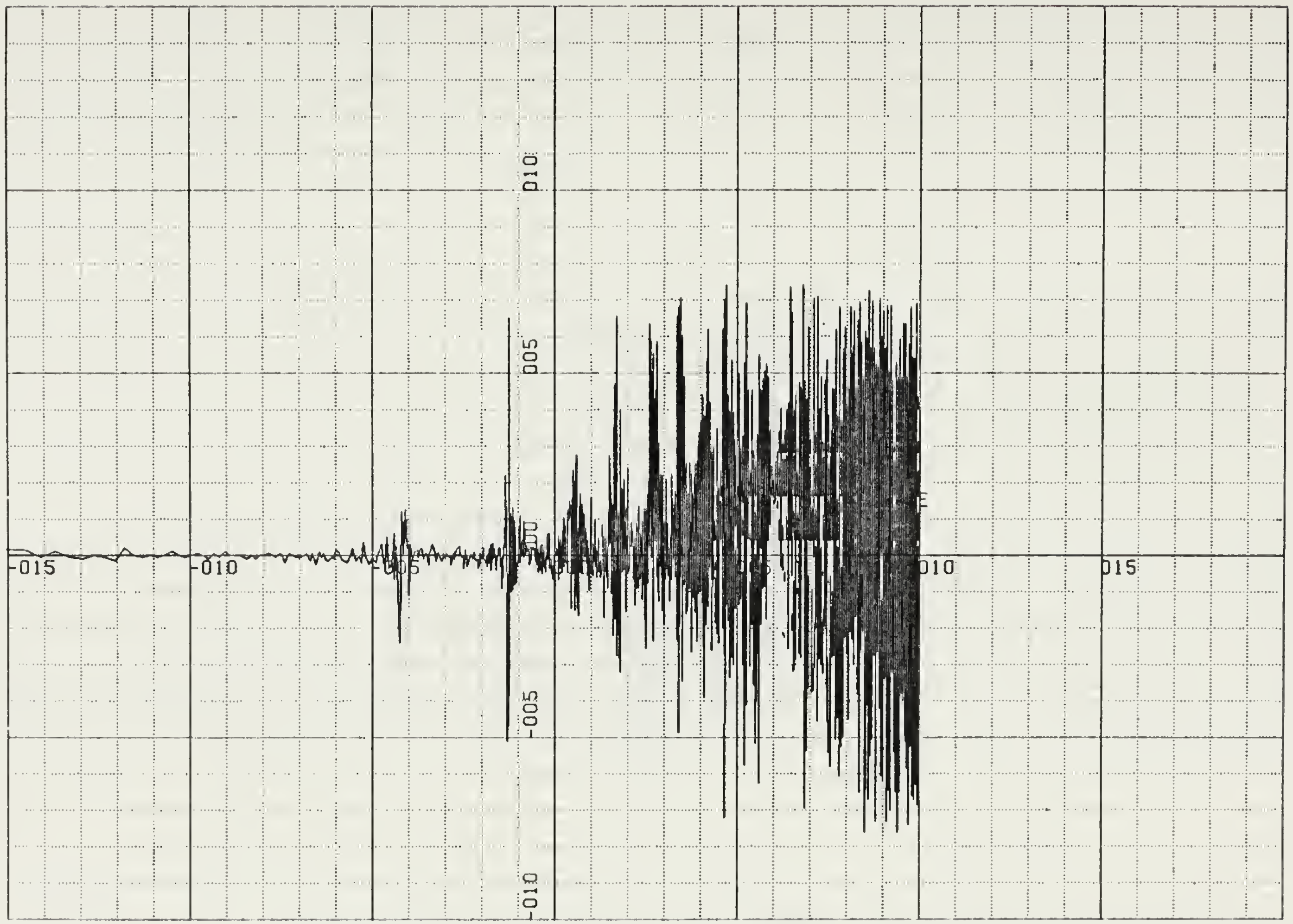

Figure 2.12. Ellipticity X-Y Plane, 17 August 82, 2240-2348 Local.
Ellipticity (0.5 unit/in) vs. Log Frequency (Hz) (0.5 unit/in)
16 Averages

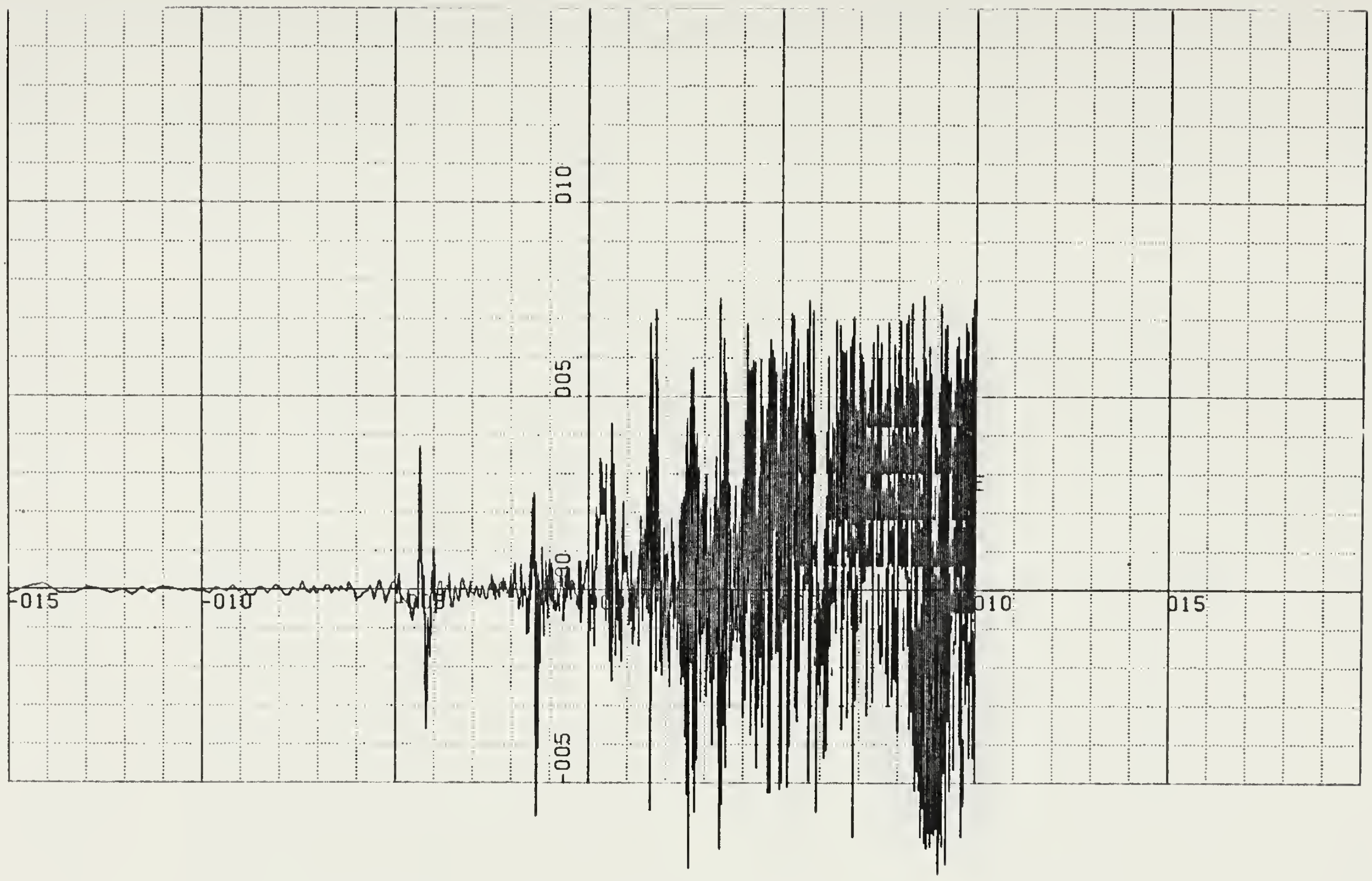

Figure 2.13. Ellipticity Y-Z Plane, 17 August 82, 2240-2348 Local. Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in) 16 Averages

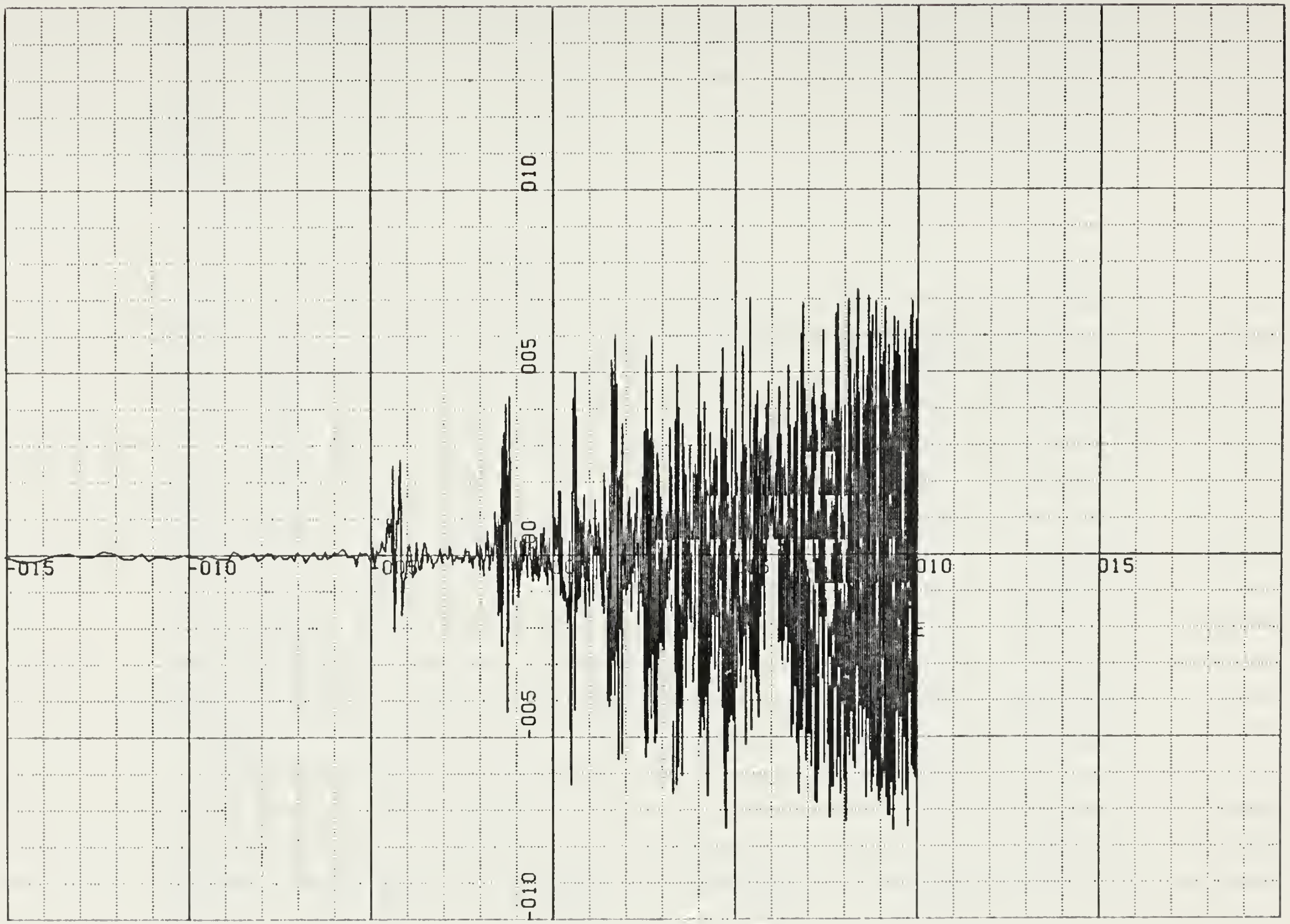

Figure 2.14. Ellipticity Z-X Plane, 17 August 82, 2240-2348 Local.
Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in)
16 Averages

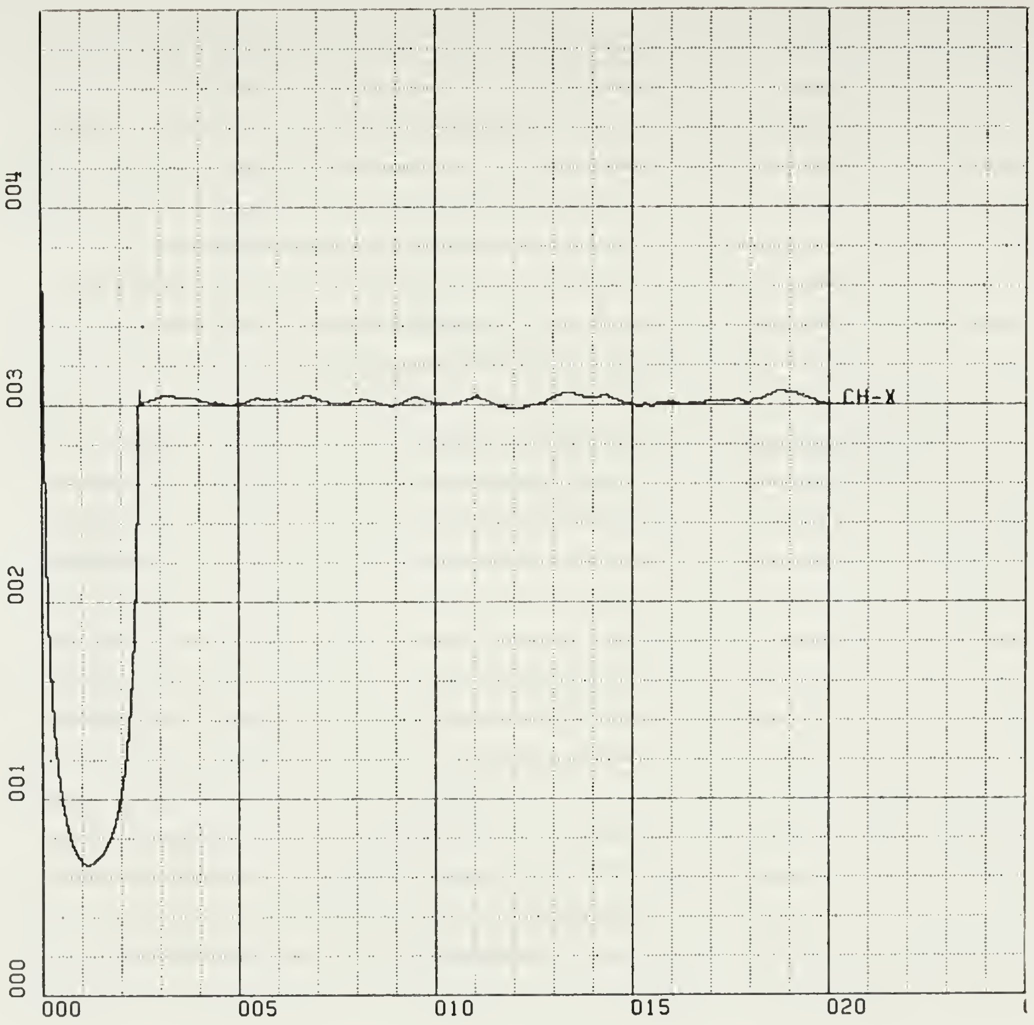

Figure 2.15. X-Coil Magnetic Field, 17 August 82, 2240-2348- Local.
Amplitude (nanoteslas : 10 units/in) vs. Time (seconds : 500 units/in)
16 Averages

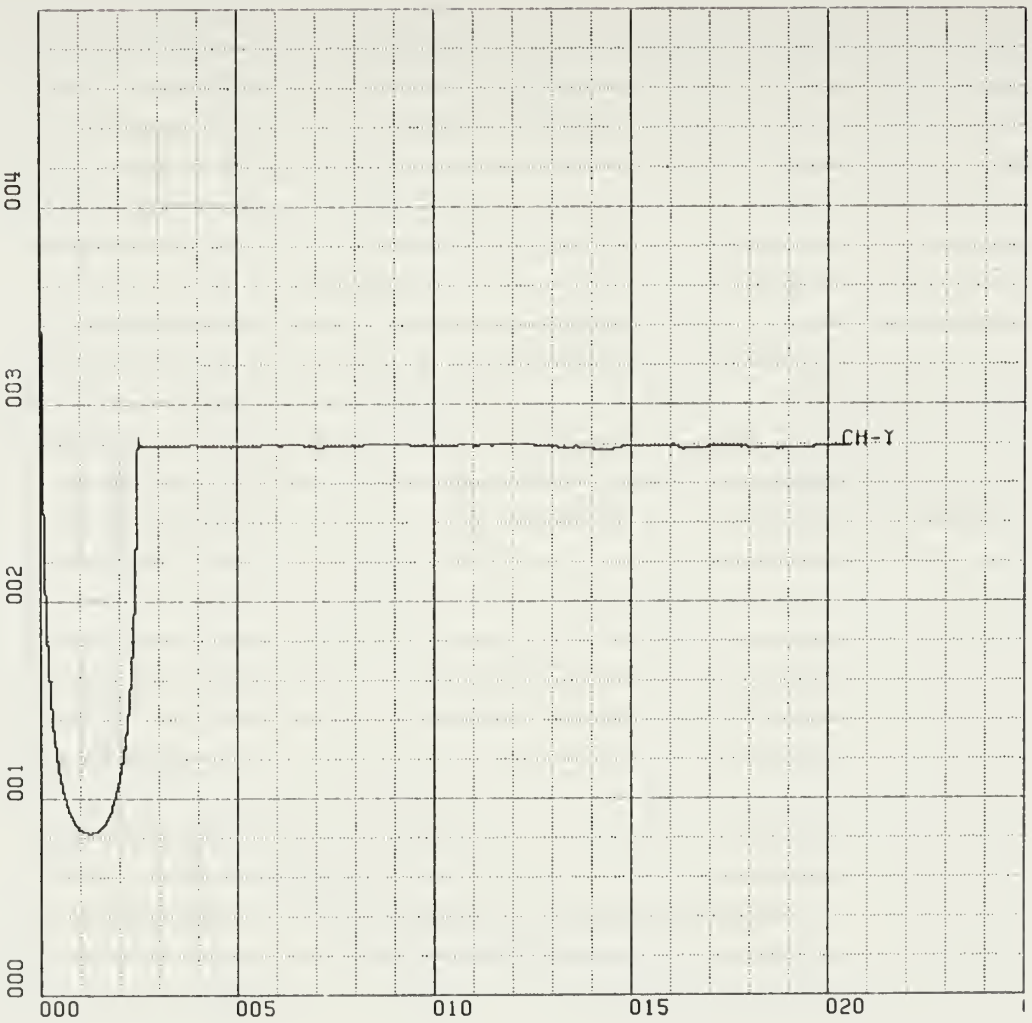

Figure 2.16. Y-Coil Magnetic Field, 17 August 82, 2240-2348 Local. Amplitude (nanoteslas : 10 units/in) vs. Time (seconds : 500 units/in) 16 Averages

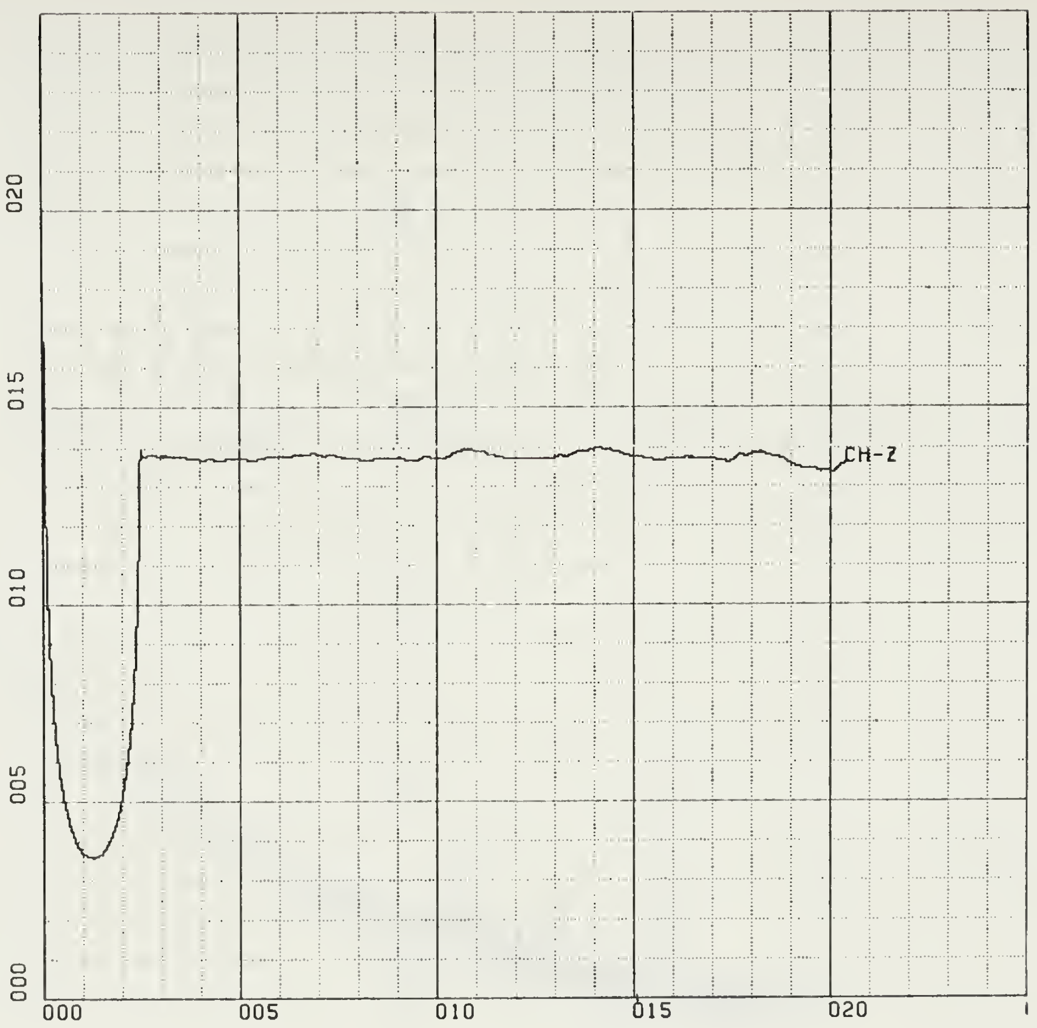

Figure 2.17. Z-Coil Magnetic Field, 17 August 82, 2240-2348 Local. Amplitude (nanoteslas : 5 units/in) vs. Time (seconds : 500 units/in) 16 Averages

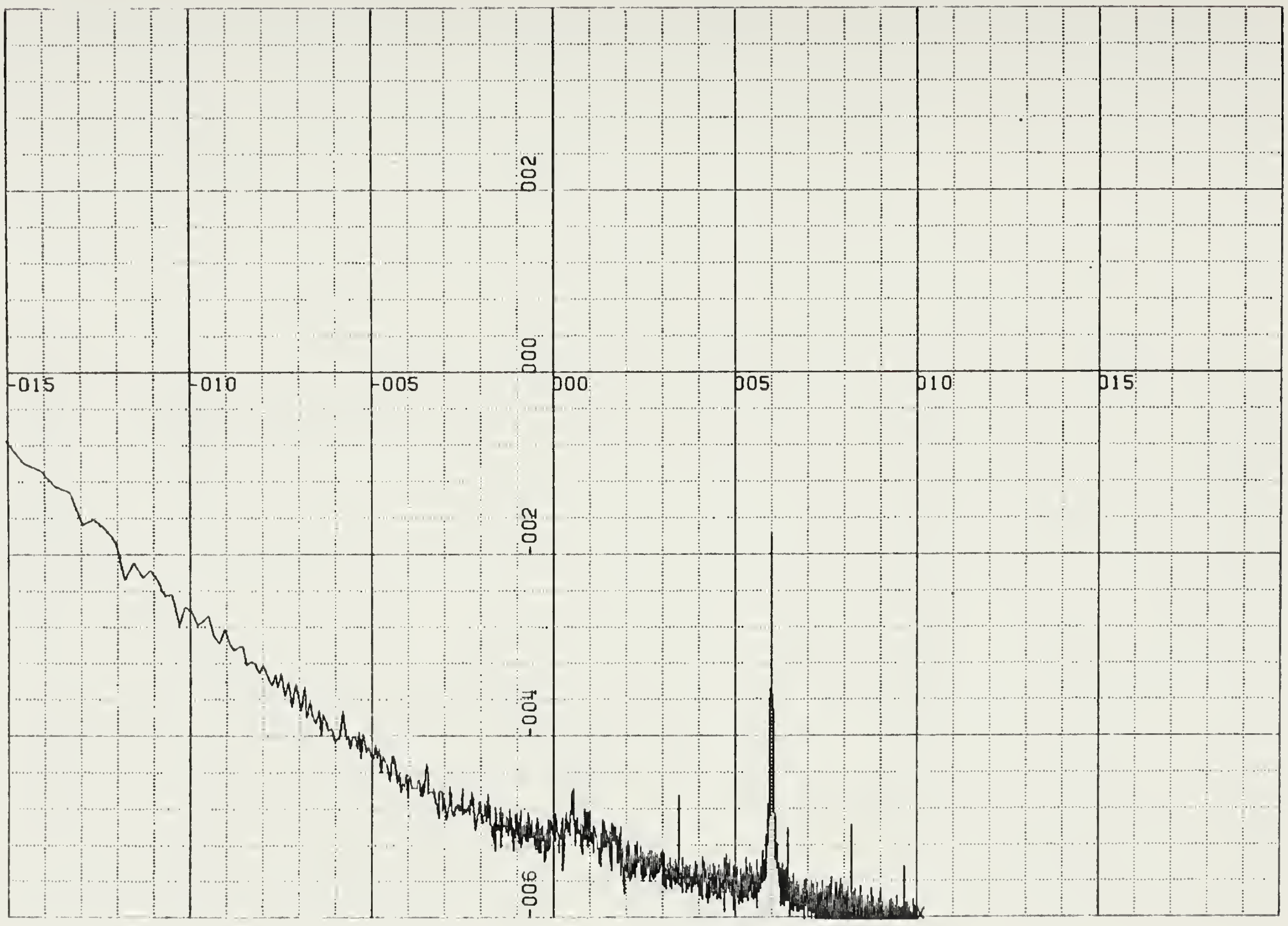

Figure 2.18. PSD X Coil, 17 August 82, 2245-2353 Local. Amplitude in dB (REF nT**2/Hz) (20 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

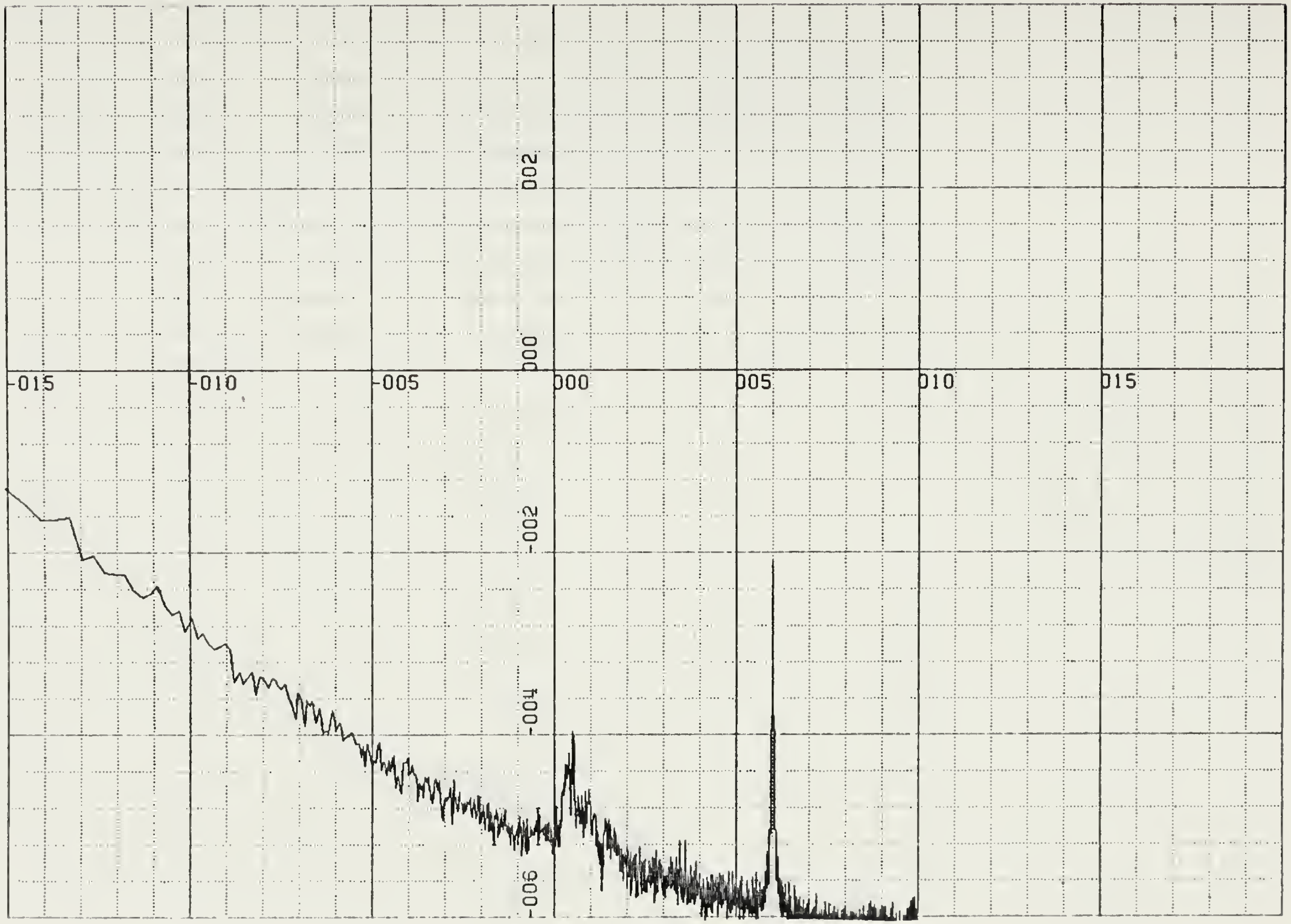

Figure 2.19. PSD Y Coil, 17 August 82, 2245-2353 Local. Amplitude in dB (REF nT**2/Hz) (20 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

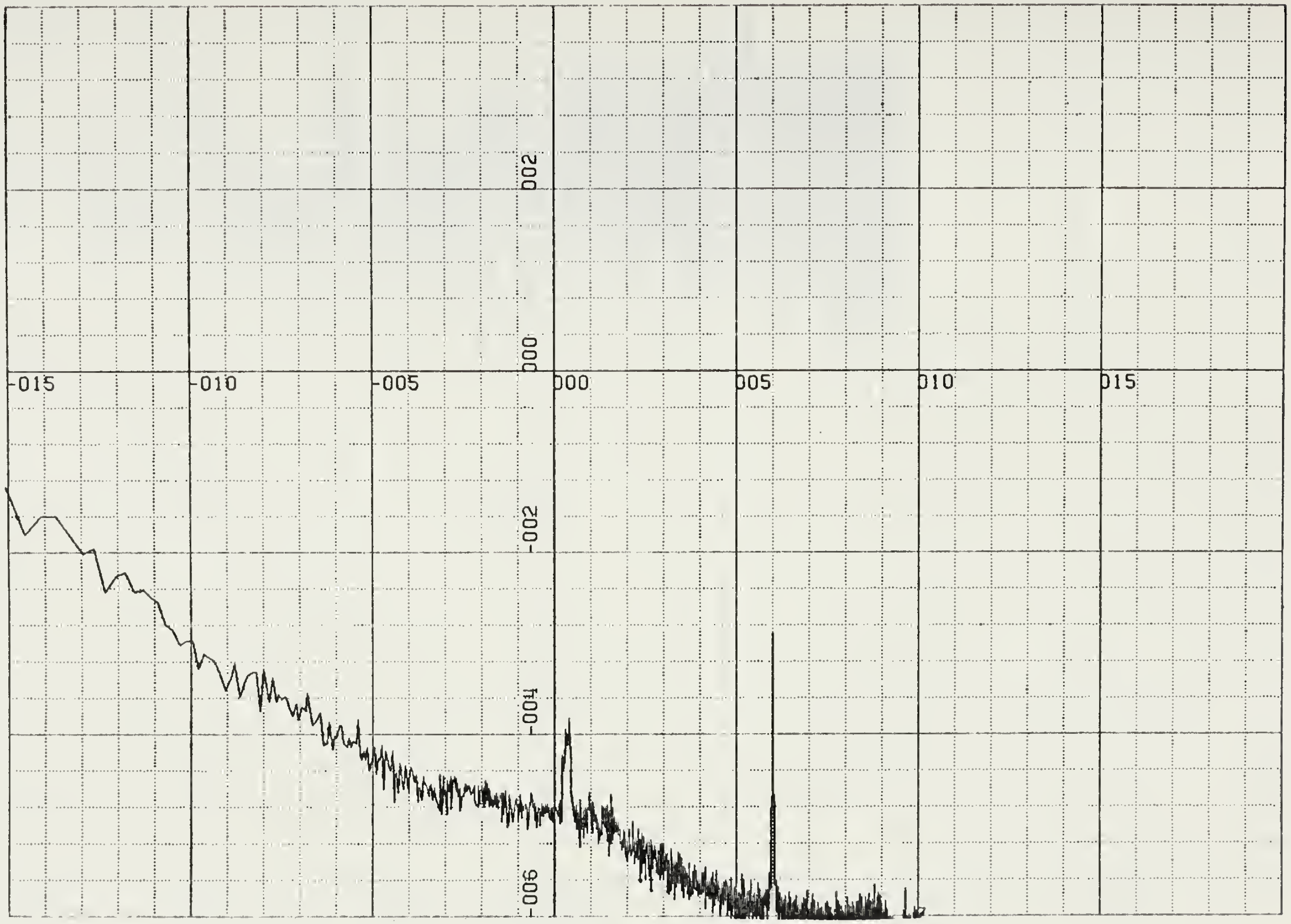

Figure 2.20. PSD Z Coil, 17 August 82, 2245-2353 Local. Amplitude in dB (REF nT**2/Hz) (20 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

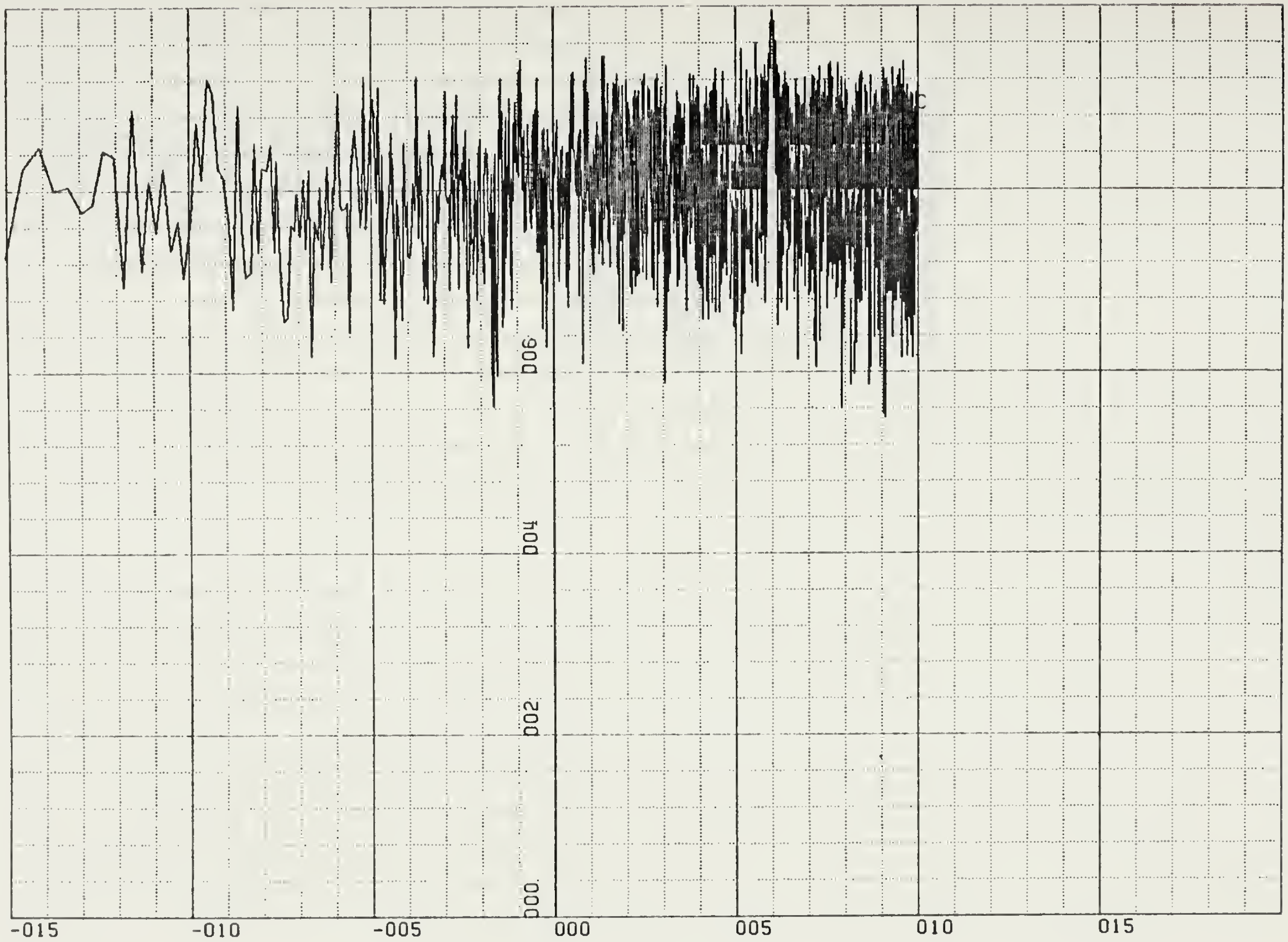

Figure 2.21. Coherence X-Y coils, 17 August 82, 2245-2353 Local. Coherence X-Y Coils (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

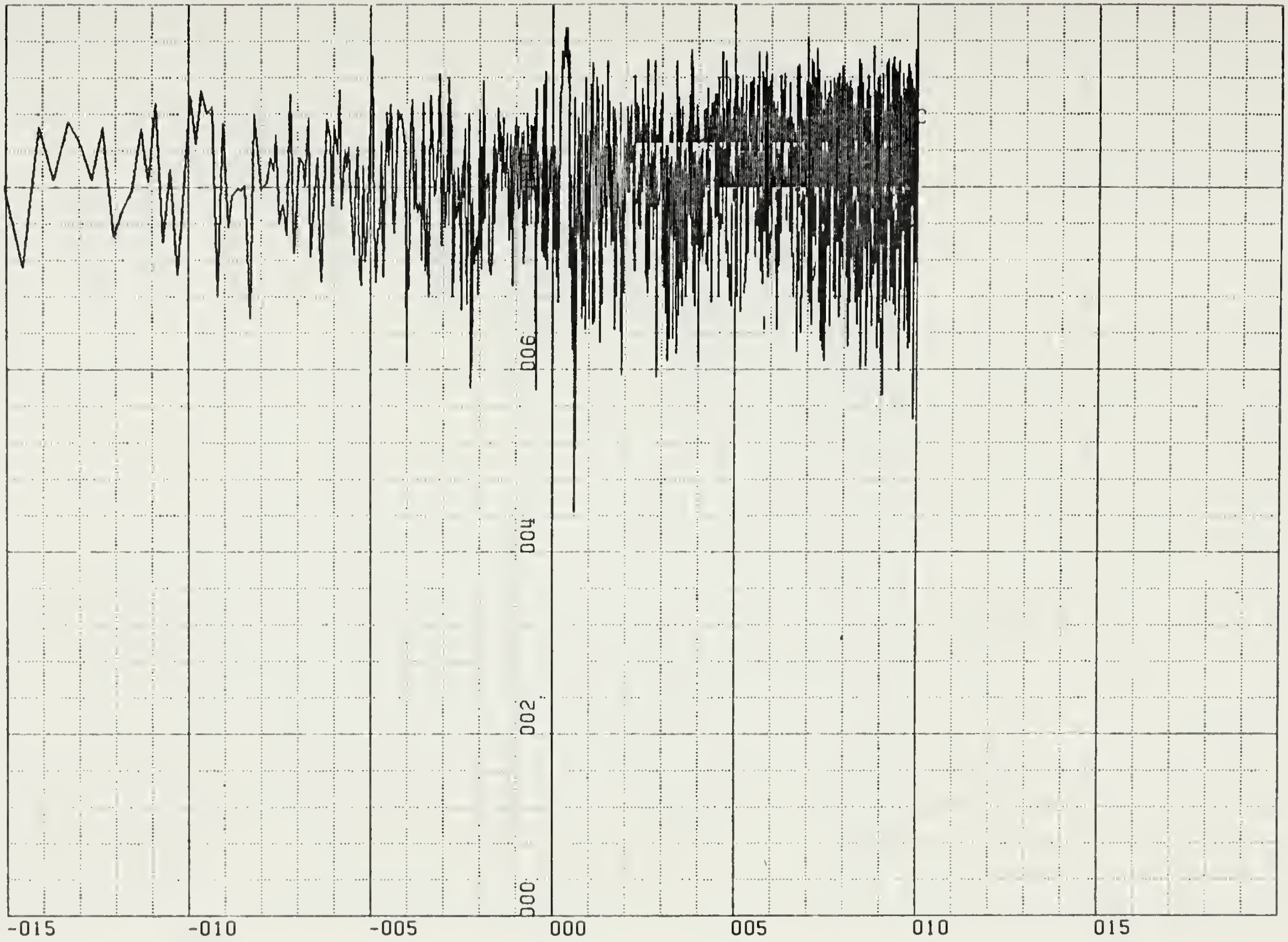

Figure 2.22. Coherence Y-Z Coils, 17 August 82, 2245-2353 Local Coherence X-Y Coils (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

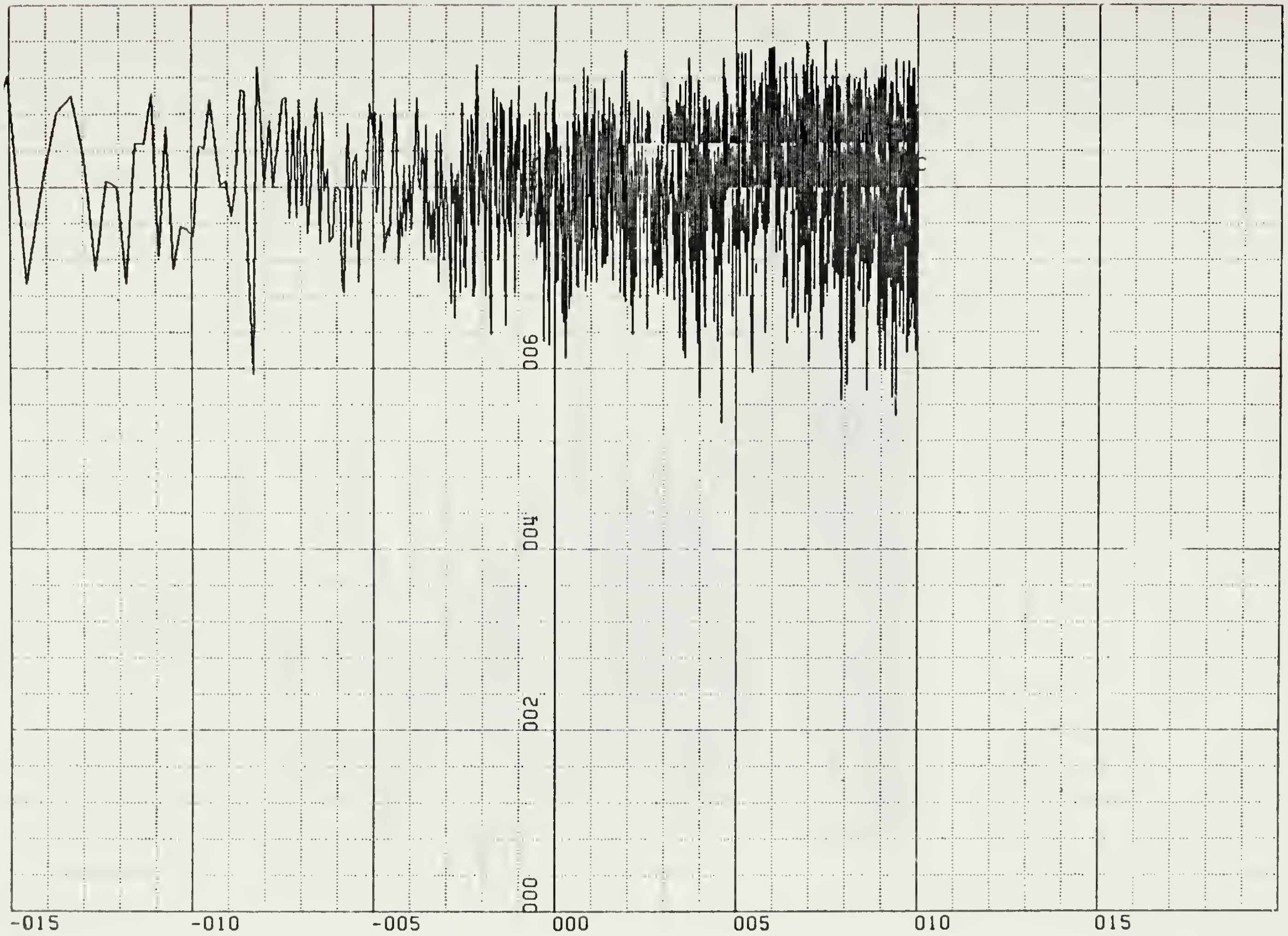

Figure 2.23. Coherence Z-X Coils, 17 August 82, 2245-2353 Local. Coherence Z-X Coils (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

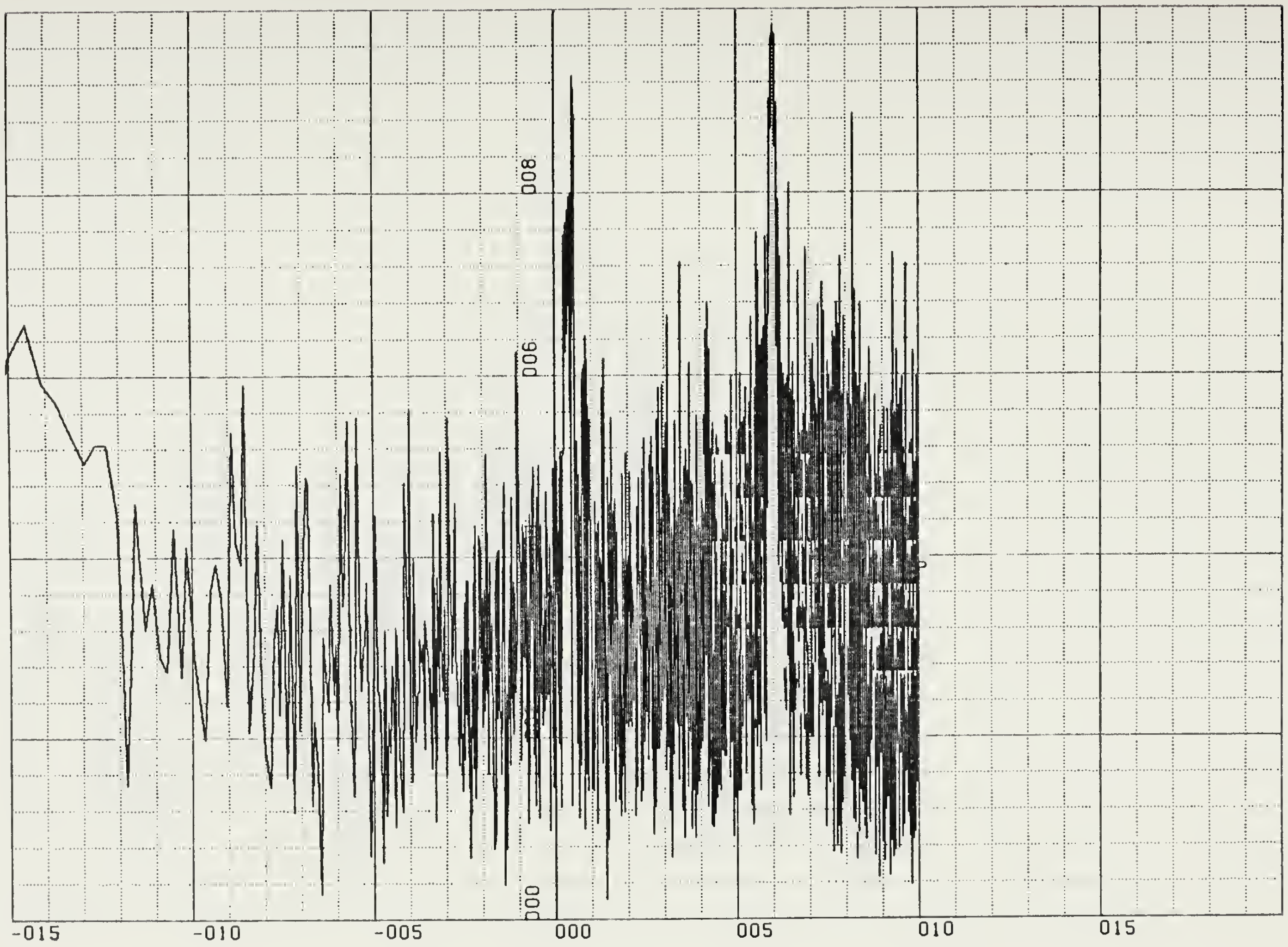

Figure 2.24. Degree of Polarization X-Y Plane, 17 August 82, 2245-2353 Local. Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

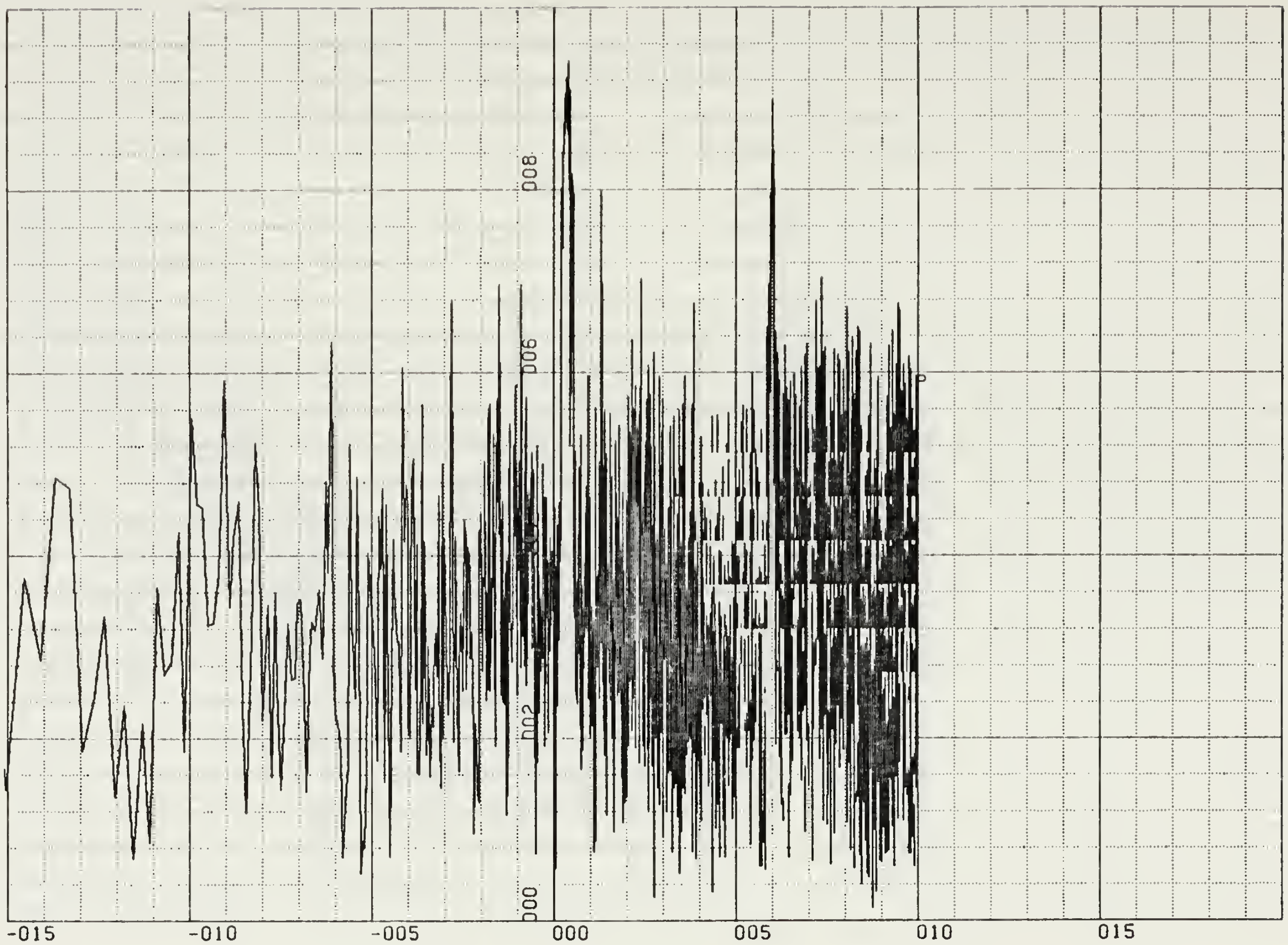

Figure 2.25. Degree of Polarization Y-Z Plane, 17 August 82, 2245-2353 Local. Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

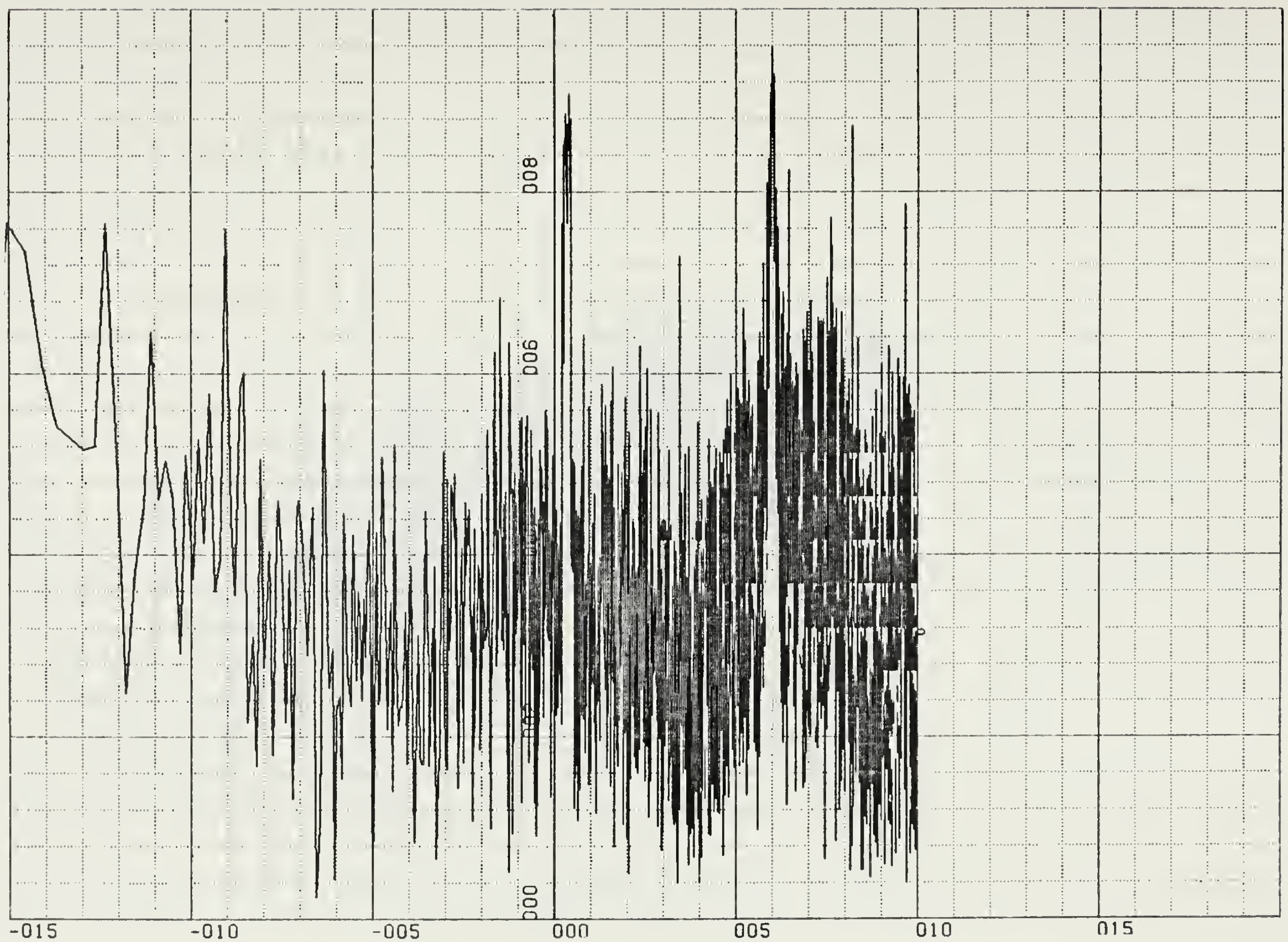

Figure 2.26. Degree of Polarization Z-X Plane, 17 August 82, 2245-2353 Local. Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

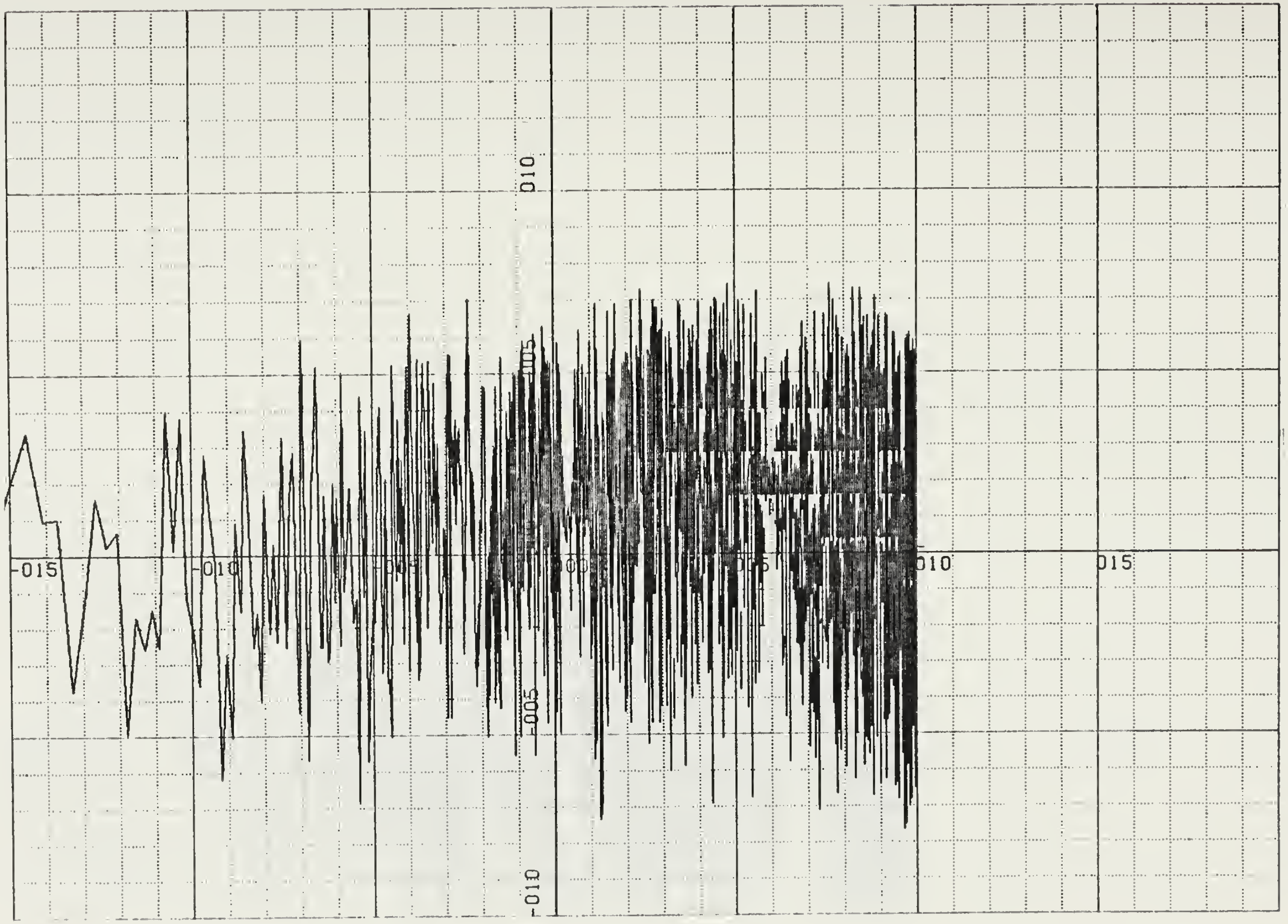

Figure 2.27. Ellipticity X-Y Plane, 17 August 82, 2245-2353 Local. Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

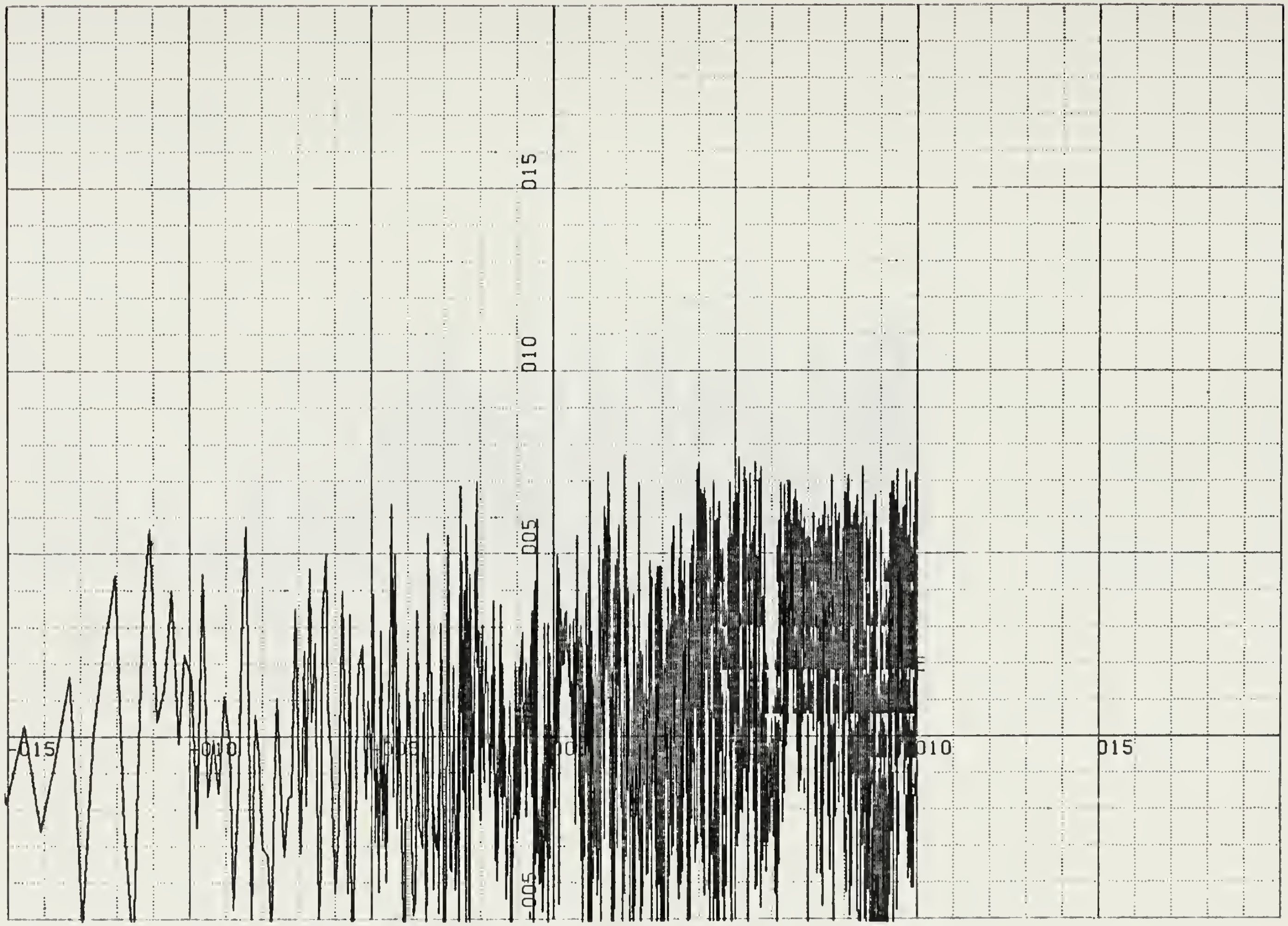

Figure 2.28. Ellipticity Y-Z Plane, 17 August 82, 2245-2353 Local.
Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in)
16 Averages

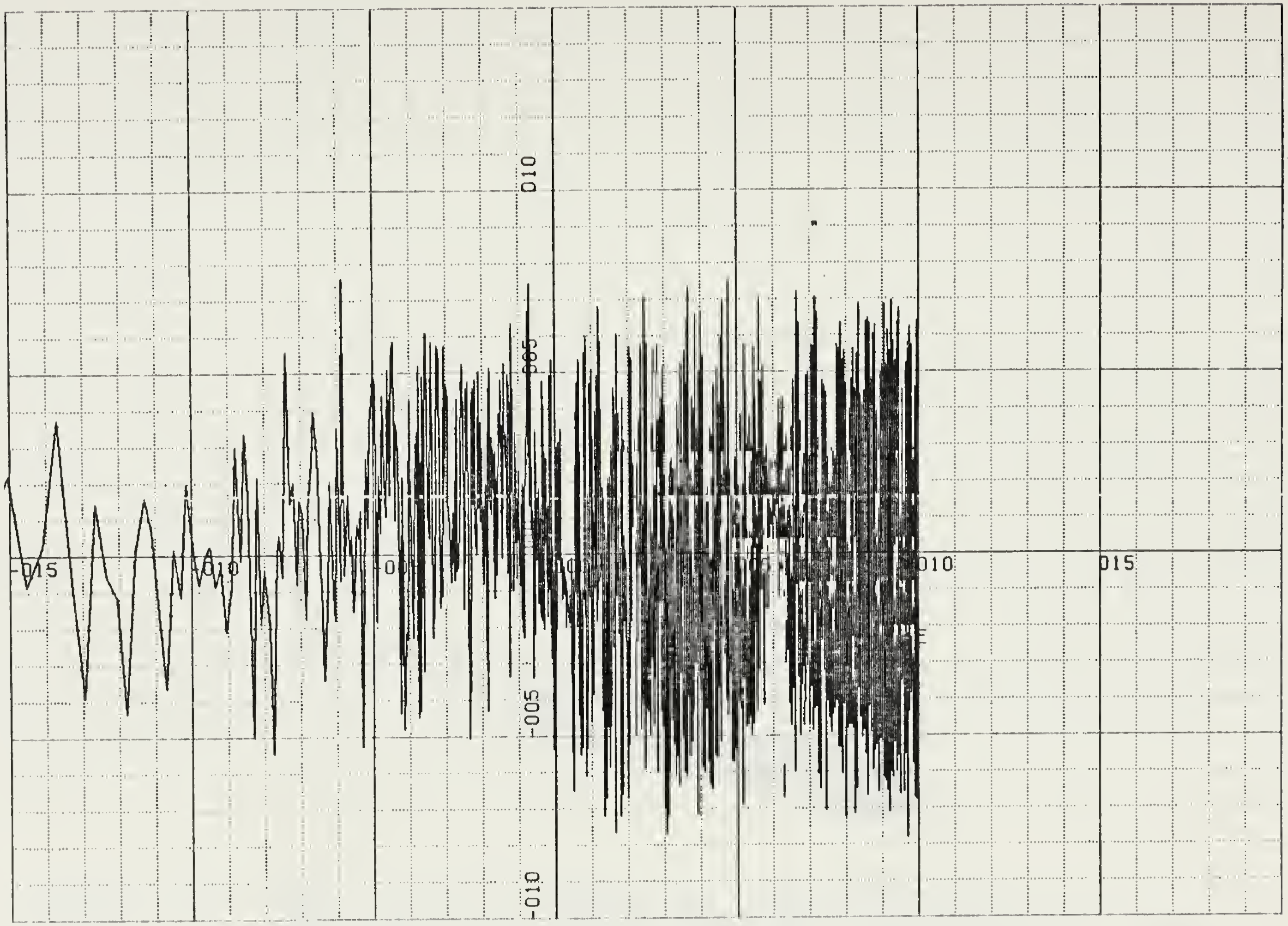

Figure 2.29. Ellipticity Z-X Plane, 17 August 82, 2245-2353 Local. Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

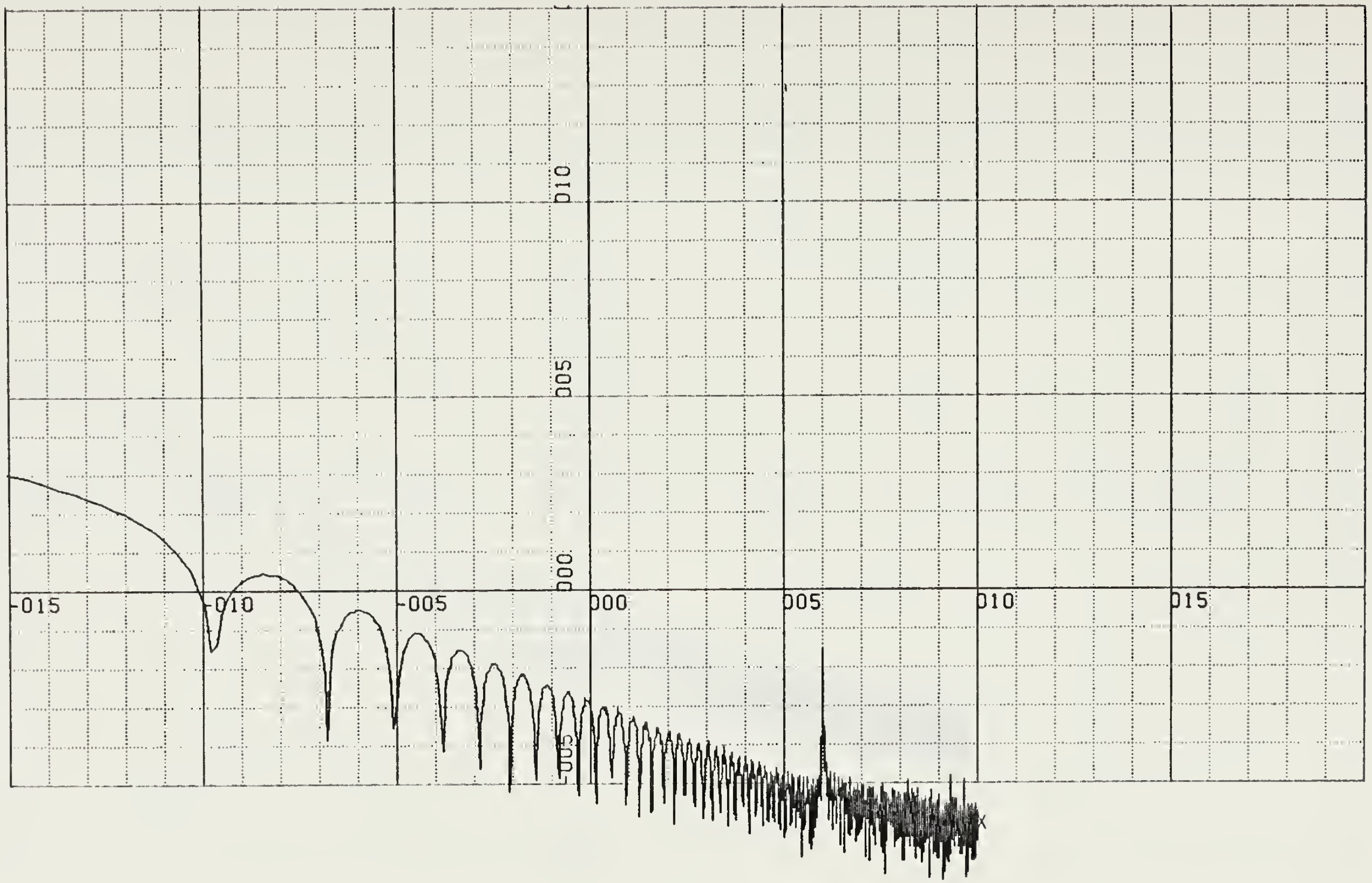

Figure 2.30. PSD X Coil, 17 August 82, 2240-2250 Local. Amplitude in dB (REF nT**2/Hz) (50 units/in) vs. Log Frequency (Hz) (0.5 units/in), 2 Averages

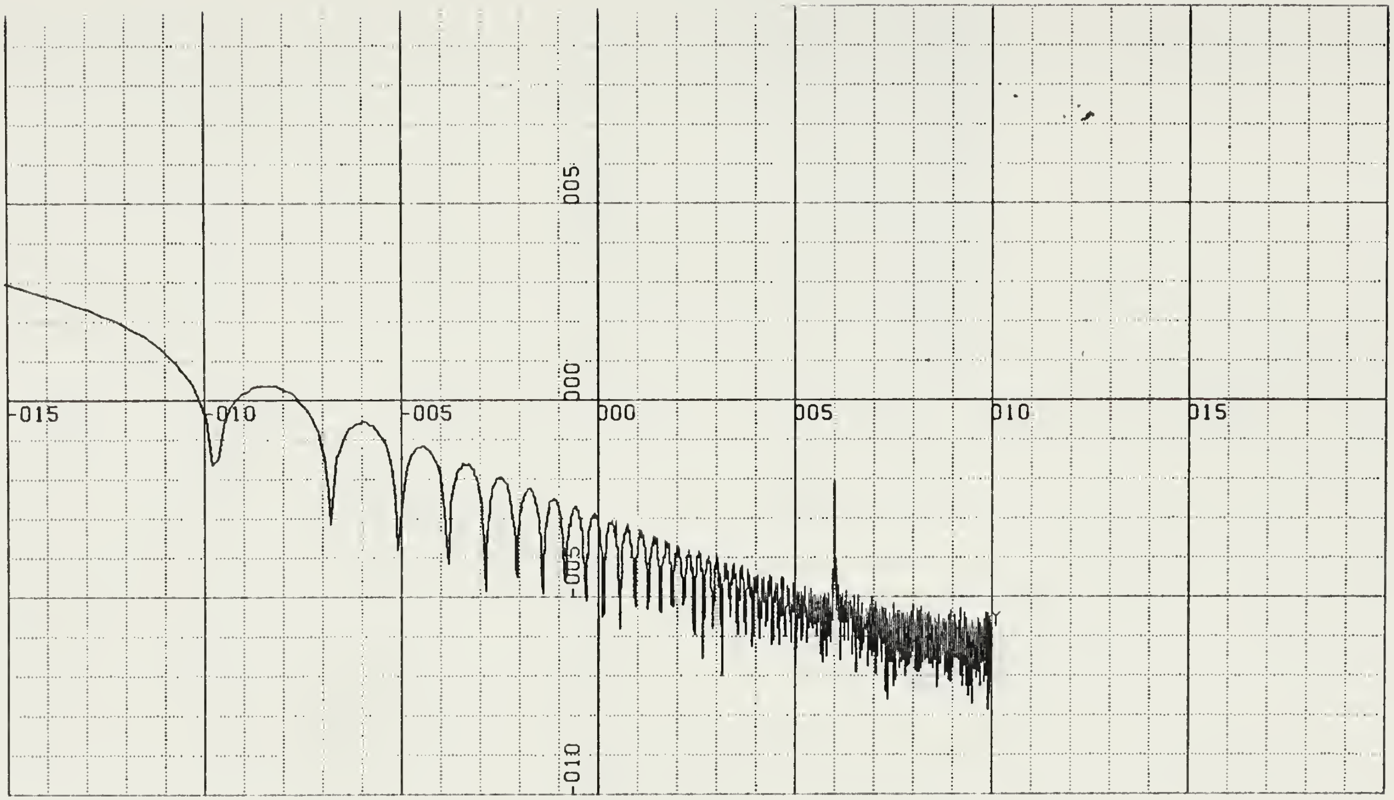

Figure 2.31. PSD Y Coil, 17 August 82, 2240-2250 Local. Amplitude in dB (REF nT**2/Hz) (50 units/in) vs. Log Frequency (Hz) (0.5 units/in), 2 Averages

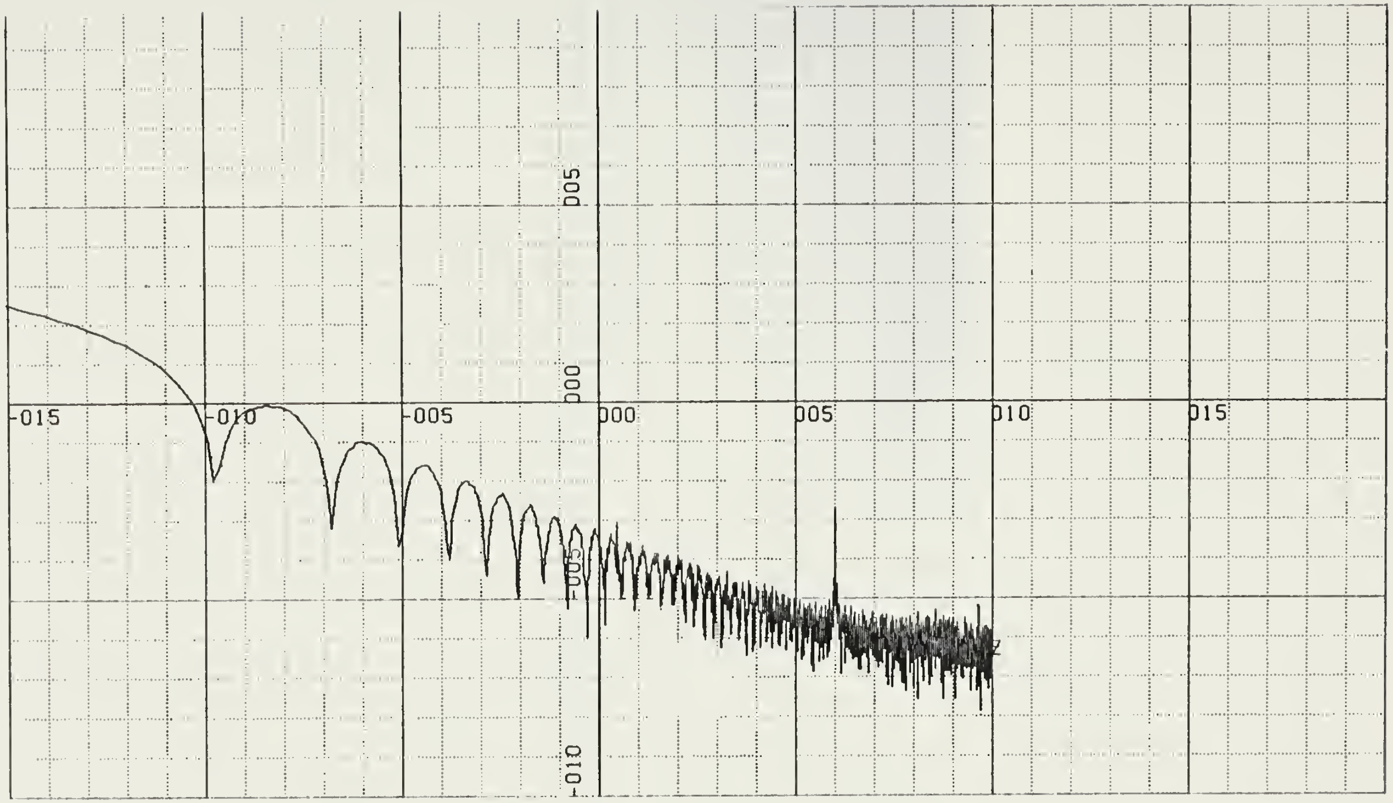

Figure 2.32. PSD Z Coil, 17 August 82, 2240-2250 Local. Amplitude in dB (REF nT**2/Hz)(50 units/in) vs. Log Frequency (Hz) (0.5 units/in), 2 Averages

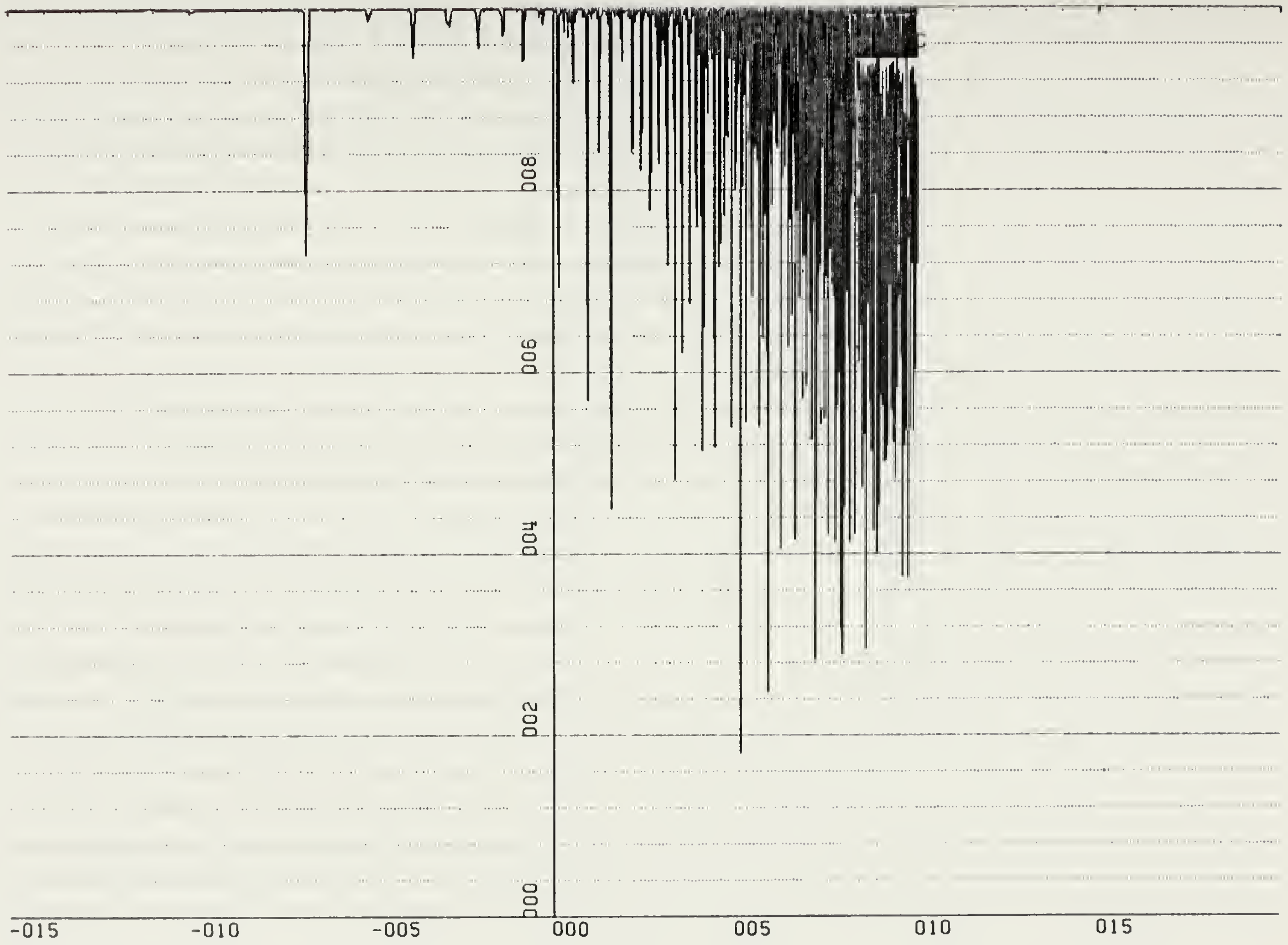

Figure 2.33. Coherence X-Y Coils, 17 August 82, 2240-2250 Local. Coherence X-Y Coils (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 2 Averages

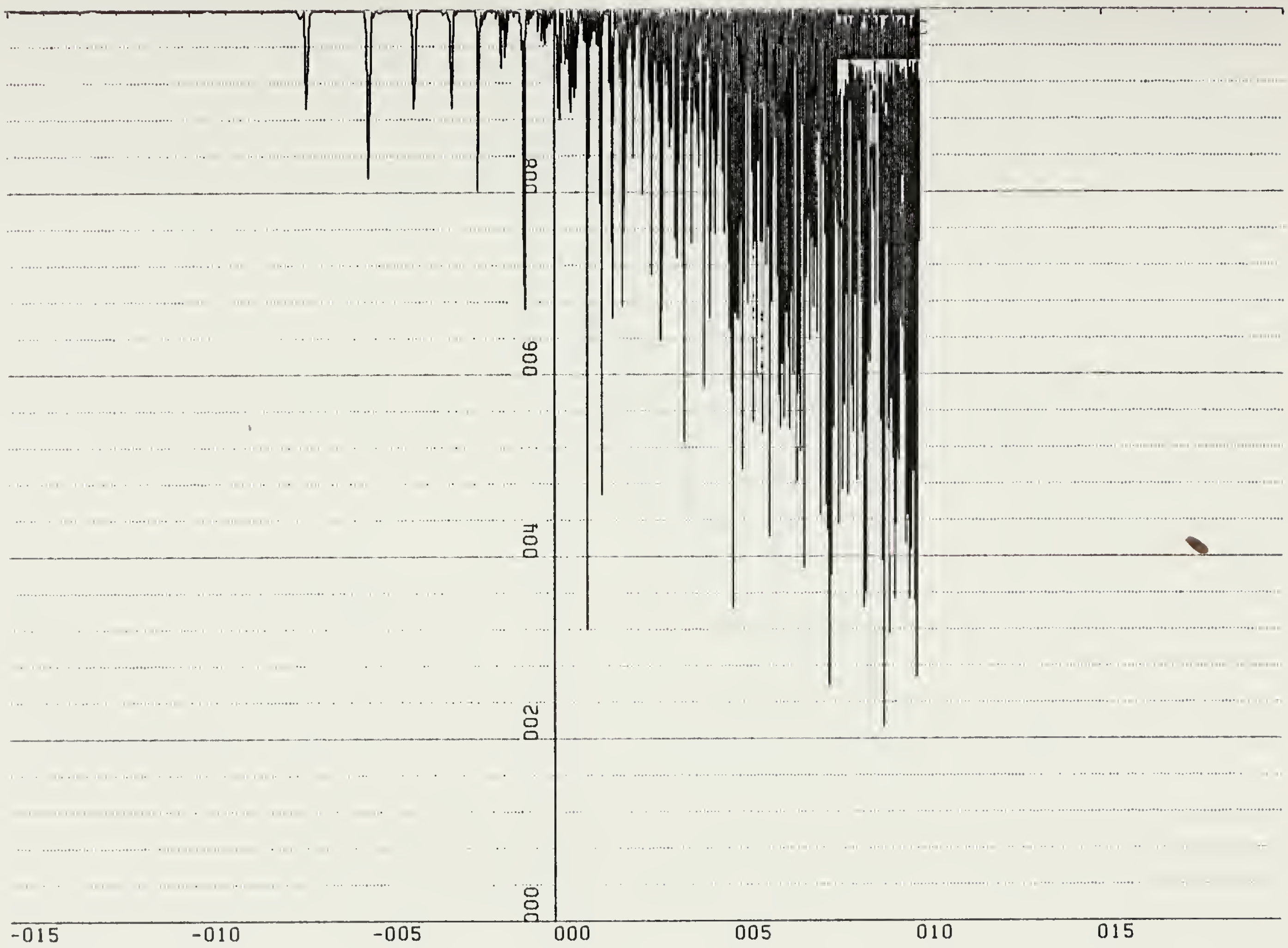

Figure 2.34. Coherence Y-Z Coils, 17 August 82, 2240-2250 Local. Coherence Y-Z Coils (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 2 Averages

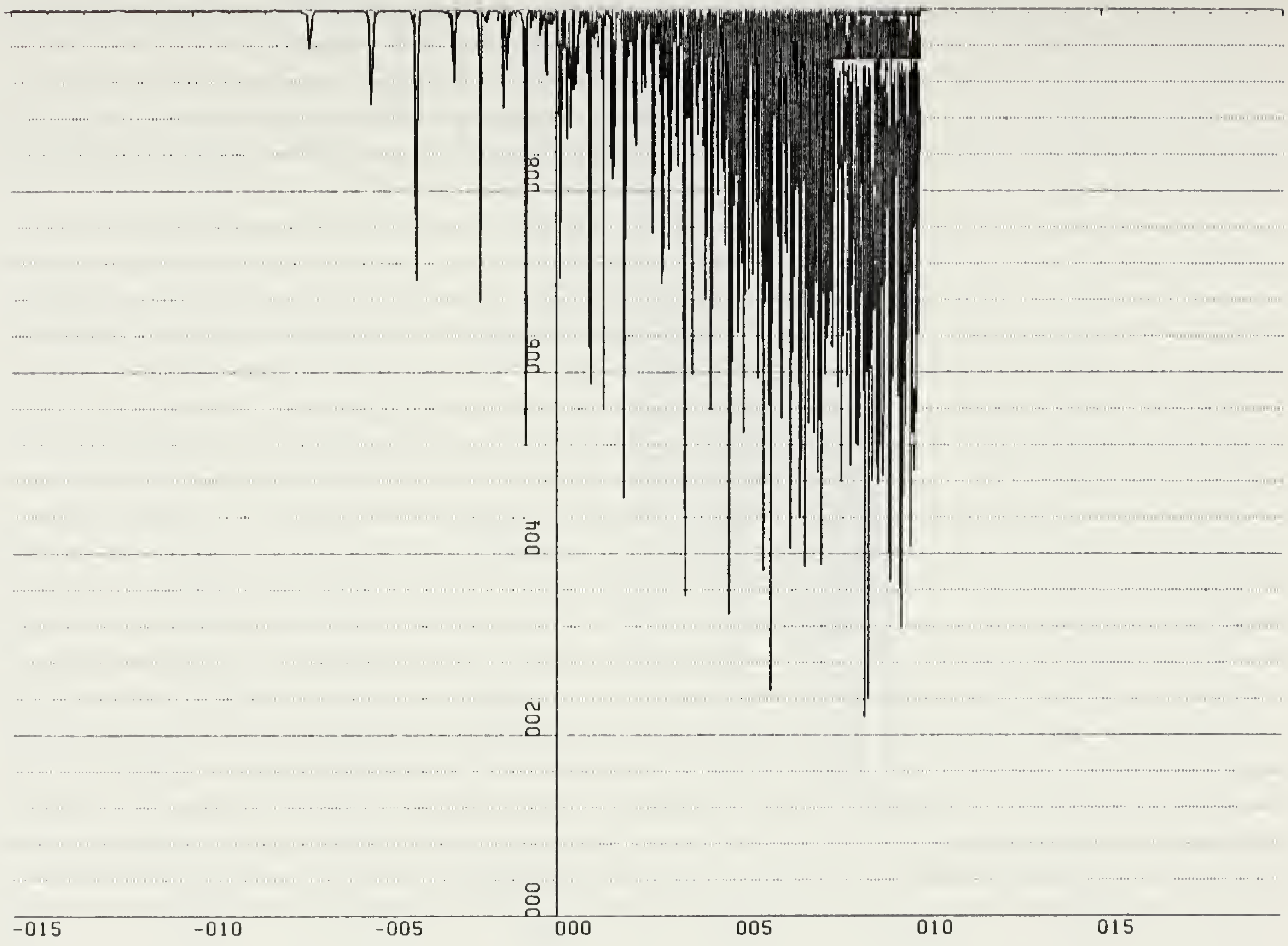

Figure 2.35. Coherence Z-X Coils, 17 August 82, 2240-2250 Local. Coherence Z-X Coils (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 2 Averages

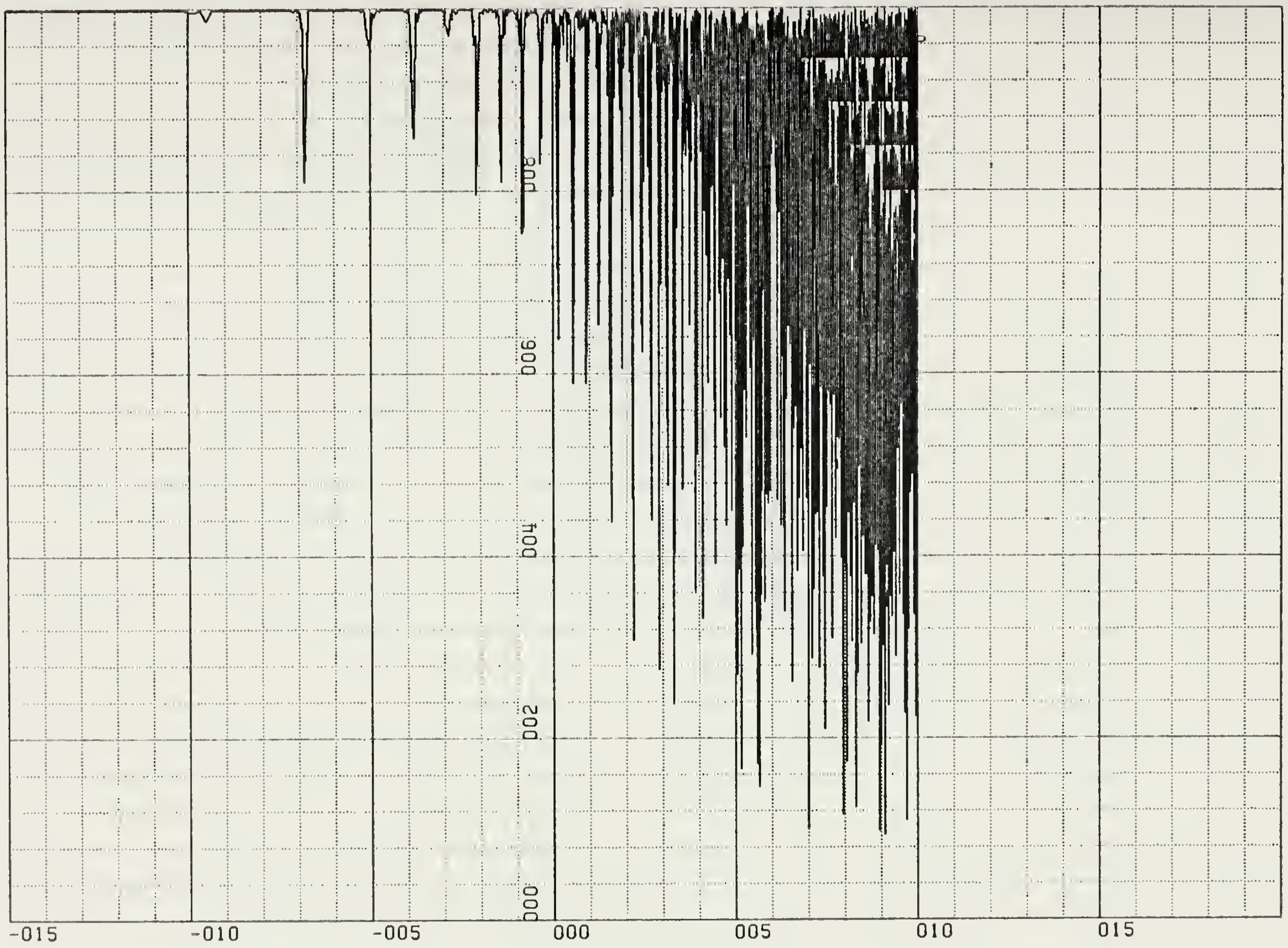

Figure 2.36. Degree of Polarization X-Y Plane, 17 August 82, 2240-2250 Local. Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 2 Averages

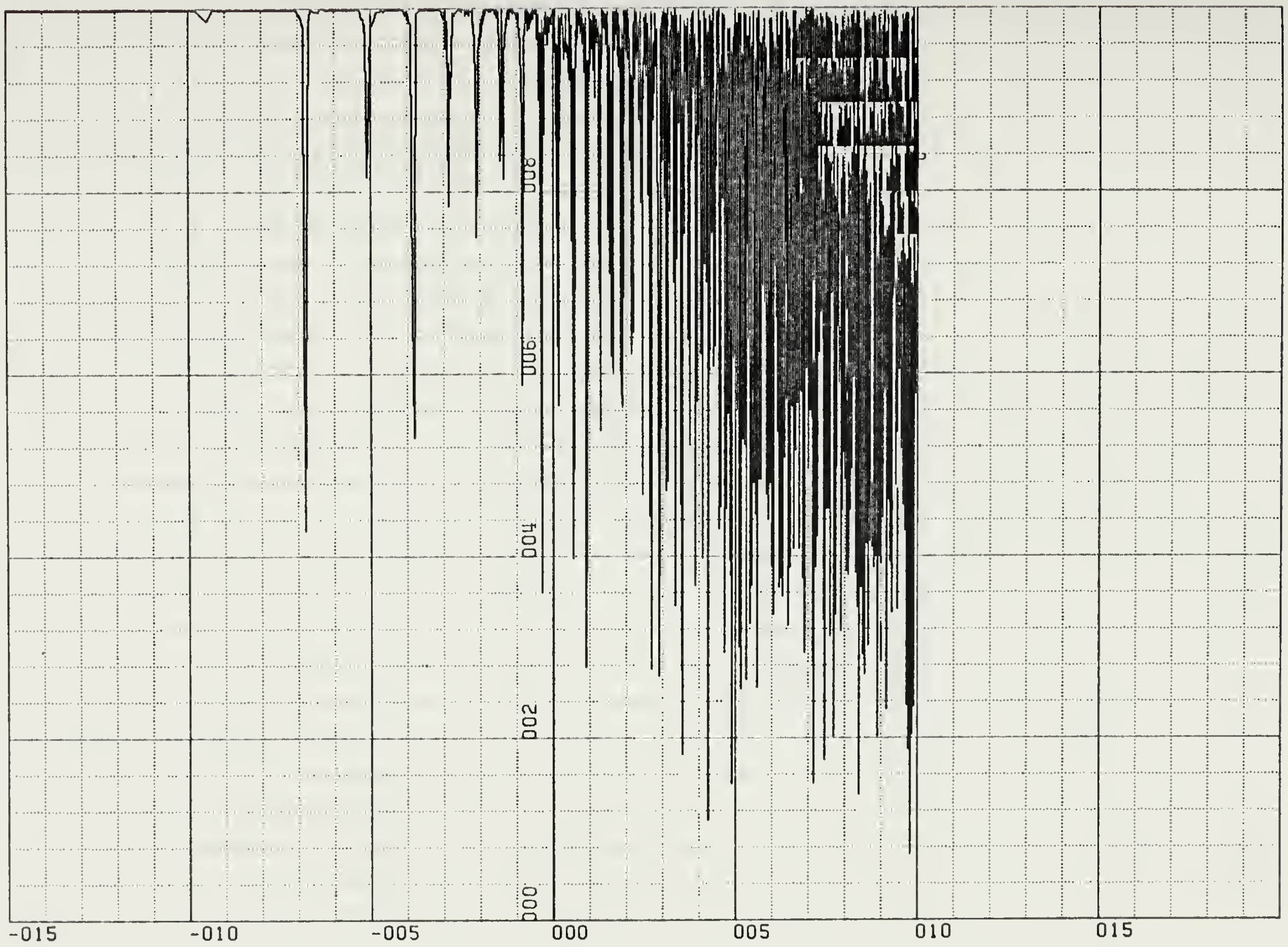

Figure 2.37. Degree of Polarization Y-X Plane, 17 August 82, 2240-2250 Local. Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 2 Averages

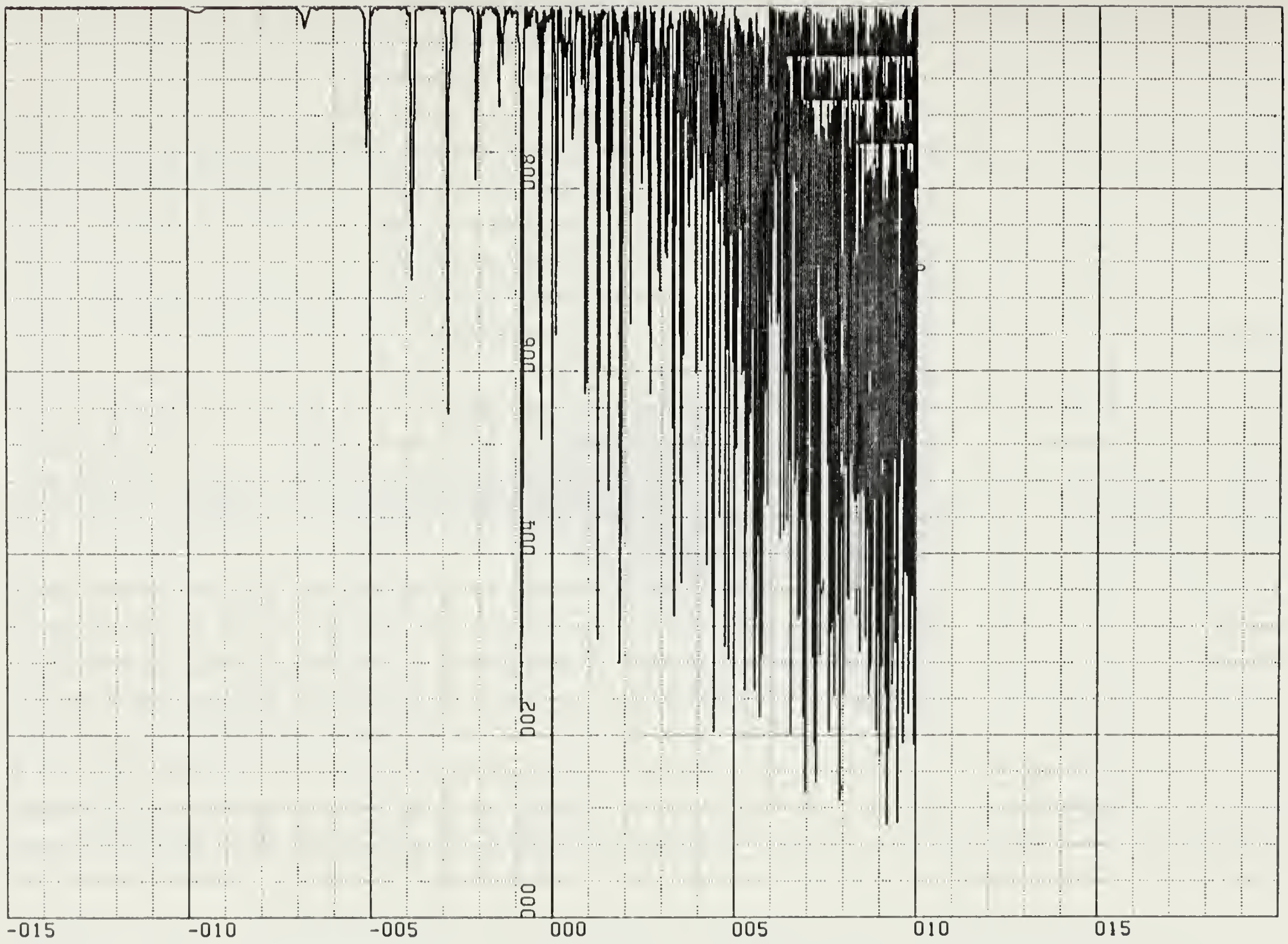

Figure 2.38. Degree of Polarization Z-X Plane, 17 August 82, 2240-2250 Local. Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz) (0.5 units/in), 2 Averages

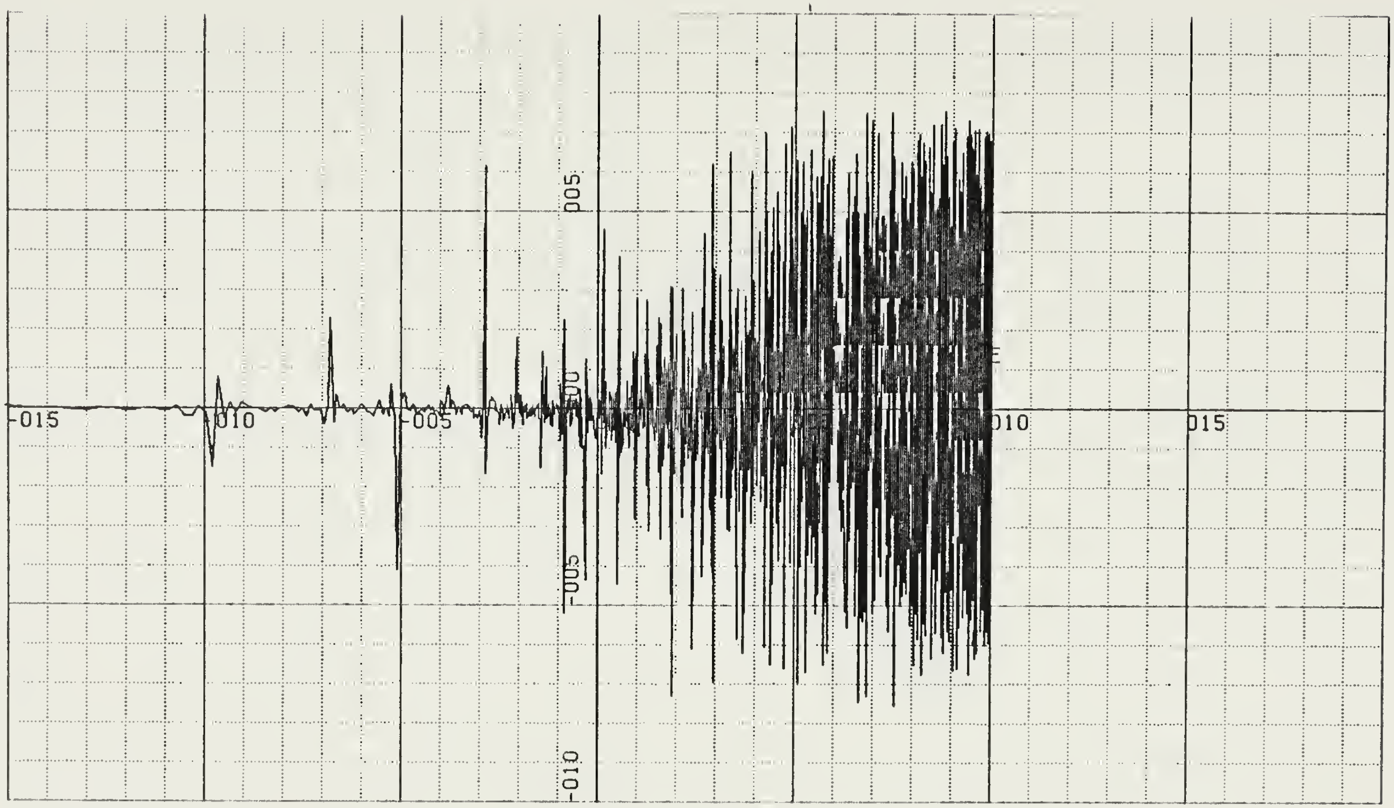

Figure 2.39. Ellipticity X-Y Plane, 17 August 82, 2240-2250 Local. Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in) 2 Averages

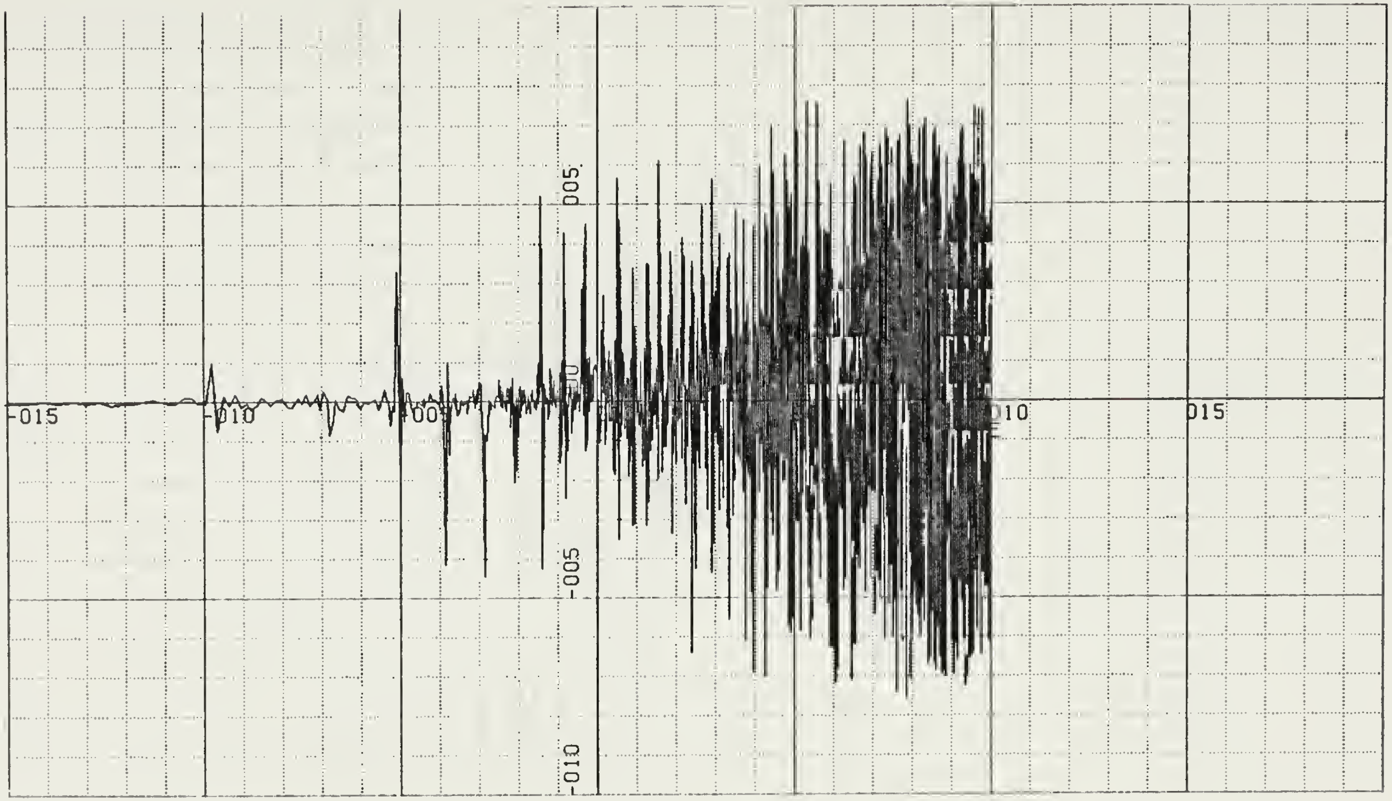

Figure 2.40. Ellipticity Y-Z Plane, 17 August 82, 2240-2250 Local.
Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in)
2 Averages

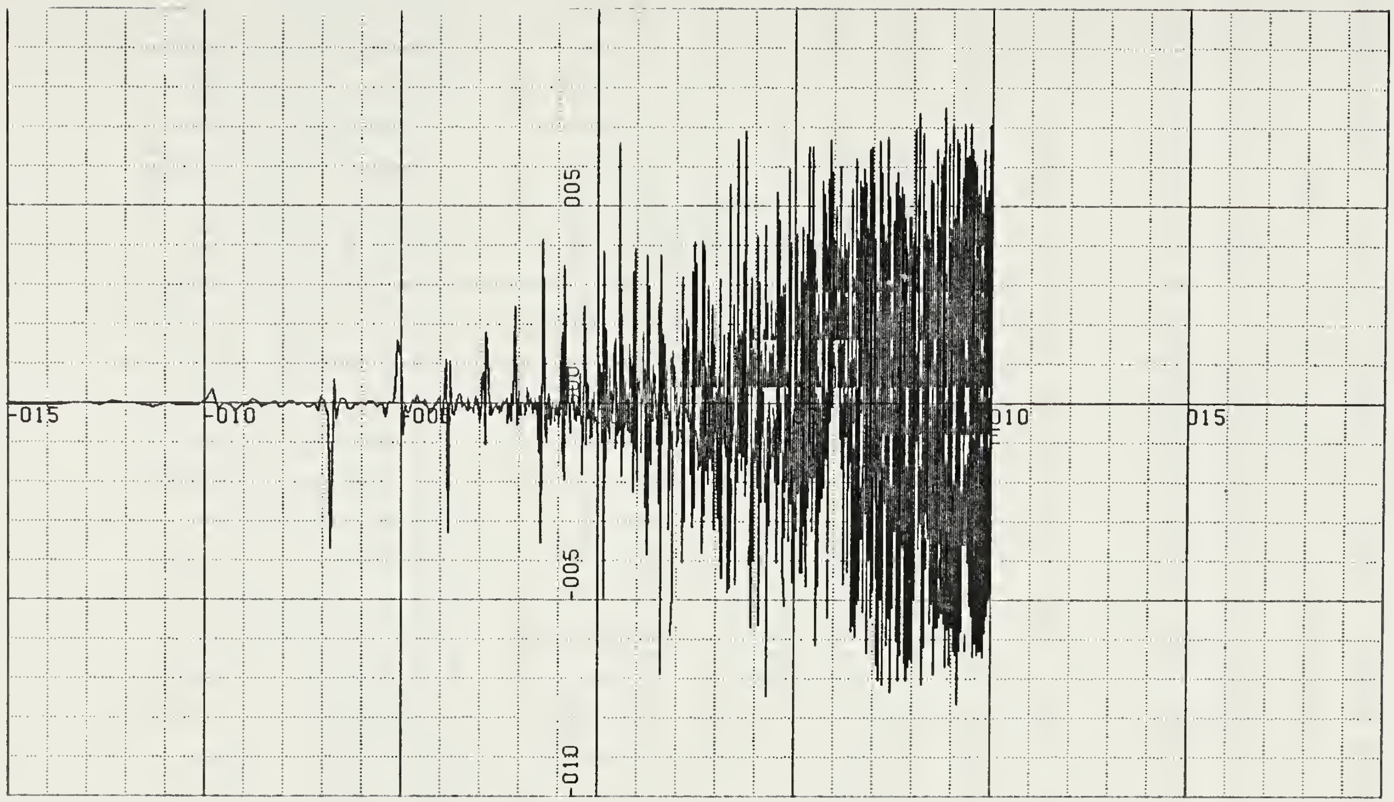

Figure 2.41. Ellipticity Z-X Plane, 17 August 82, 2240-2250 Local. Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in), 2 Averages

recommended at the beginning of the programs producing the above mentioned plots. Time series plots should also be made to provide a further check.

An explanation of the source of the large fluctuations is that the PCM to digital conversion begins before the actual PCM data starts on the tape. The decoding equipment considers the noise on the section of tape before the PCM data starts as signal.

The above analysis clearly proves that the "hump" like structure in the PSD's and the "nice" behavior observed in the corresponding coherence, ellipticity and degree of polarization are artifical and do not represent any real phenomena in the geomagnetic field. Thus, the data in Figures 2.3-2.14 and Figures 2.30-2.41 does not appear to be reliable. Unfortunately, this artificially induced, and therefore unphysical, behavior of the polarization has been published recently [Ref. 7]. The conclusion found in Reference 7 that

> Geomagnetic fluctuations in land are well polarized below 1.0 Hz and that the polarization is quite frequently, though not consistently, linear. The situation under the sea is similar. Furthermore, a land-sea coherence study in the horizontal plane showed very high coherence below 1.0 Hz.

are not substantiated by the physical data. Plots of the artificially induced behavior are published in References 1, 2, and 3.

The 4 Hz peak present in the PSD's shown in Figures 2.18-2.20 is the result of 60 Hz aliasing. 60 Hz magnetic fields generated by local power lines exist at the measurement site. Digitization at a 32 Hz or 64 Hz rate of the analog voltages from the sensing coils shifts the true frequency of the power line signals down at 4 Hz. The 60 Hz aliasing results in the anomalis behavior at 4 Hz seen in the coherence, degree of polarization and ellipticity plots shown in Figures 2.21-2.29.

Another peak is present at about 1.2 Hz for the PSD's in Figures 2.18-2.20. For this data set, the 1.2 Hz signal correlates with a 1.2 Hz signal identified in the time series data. The origin of the 1.2 Hz signal is unknown. The 4 Hz and 1.2 Hz peaks are of little concern in this study since both are well above the frequency of the micropulsation analyzed.

Another "suspicious" feature of the PSD's is the large amount of hash appearing from 2 to 10 hertz. We will gain further insight into this problem in analyzing the time series voltage data.

From the analysis of the abnormal behavior in the PSD's, coherence, etc., future coil data sets should receive a balanced treatment between the time domain and the frequency domain to avoid misinterpretation.

III. TIME SERIES DATA

A. TIME SERIES VOLTAGE DATA

1. Voltage Software

The importance of time series data as a check became evident when we uncovered the problem with the initial PSD's, coherences, etc. Computer code was developed to produce both unsmoothed and smoothed times series voltage plots. The reason for producing both smoothed and unsmoothed voltage plots will become apparent in the time series voltage analysis section. Time series voltage plots could provide a means of monitoring the data for system "glitches" which might later produce erroneous PSD's, etc., and suspicous features on time series magnetic field plots.

The Fortran computer program that produces the voltage plots is compiled and run on the Naval Postgraduate School IBM 3033 VM or "batch" system. Both the unsmoothed voltage program (VOLTR) and the smoothed voltage program (VOLTS) require 2.048 megabytes of core memory and approximately 15 minutes of central processor unit (CPU) time to run. These figures provide a comfortable margin to insure that the program does not "bomb" due to lack of core or run time.

The design of both VOLTR and VOLTS is the same with the exception that a smoothing algorithm is applied to the data in the case of VOLTS. Both programs have incorporated in them the digital tape advance package using ISEC as the number of

seconds one wishes to advance the tape. Data is read off the digital tape in blocks of 8192 frames by the subroutine RD referenced earlier. As before, this data is in integer form and represents voltages between ±5 volts by numbers between 0 and 4096. The integer representing 0 volts is ideally 2048, however, I found that the "real" zero values wander. The reason for this "wander" is not understood. For good results, the following values worked well for the respective coils.

X-coil : zero = 1966
Y-coil : zero = 2085
Z-coil : zero = 2539

The voltage values normalized to ±5 volts are placed in new real arrays. At this point the next block of data is read off the digital tape and goes through the same process. VOLTR and VOLTS analyze eight blocks or 34 minutes of data. The linear arrays holding the voltage data are dimensioned to 65,536 elements given a sampling rate of 32 samples/second. For every one of the 65,536 voltage values there is a time value in another array. Thus four arrays are required to handle the data, three arrays containing voltage data and one that contains the respective times for each of the measurements. At this point, the VOLTR program calls the NONIMSL subroutine DRAWP to plot the data. The VOLTS program uses a smoothing algorithm to reduce the amount of high frequency hash.

The smoothing algorithm is a double running point average executed on all three axes of data. Since I was

interested in periods of approximately 10-45 seconds, I averaged over 144 points. With a running average over 23 percent of the oscillation, the unwanted background can be removed without destroying the oscillations. Averages greater than 50 percent of the period would partially remove the oscillation of interest. The construction of the algorithm makes changing the number of points averaged over trivial. One need only change a loop index and three divisors to obtain a different average. The smoothing algorithm is provided as Table 3.1. The computer code for both VOLTR and VOLTS is attached in Appendix A and Appendix B.

2. Time Series Voltage Data Analysis

One can gain a great deal of insight into the contents of the data by looking at the smoothed and unsmoothed voltage products. Figures 3.1-3.3 are unsmoothed voltage plots representing the first 34 minutes of the digital data tape GMDT 11 recorded 17 August 82, 1301-1408 local time. A one minute tape advance was used in producing this data. Immediately one notices the large amount of 60 hertz aliasing in the time series unsmoothed voltage. The 60 hertz aliasing appears as 4 hertz because of the 32 sample/second sampling rate. The sensing system has a low pass filter that should be improved to remove the aliasing problem. The 4 hertz background can be seen more clearly in Figures 3.4-3.6. Above the 60 hertz aliasing background, we see voltage spikes ranging in magnitude from 1 volt to over 4 volts. Expanding the time scale to 50

Table 3.1. Smoothing Algorithm

```
      DO 73 L2=1,2
      Q=0
      DO 74 IS=1,65318
      SUMX=0.0
      SUMY=0.0
      SUMZ=0.0
      DO 75 J=1,144
      SUMX=ZZX1(Q+J)+SUMX
      SUMY=ZZY1(Q+J)+SUMY
      SUMZ=ZZV1(Q+J)+SUMZ
75    CONTINUE
      ZZX1(IS)=SUMX/144.
      ZZY1(IS)=SUMY/144.
      ZZV1(IS)=SUMZ/144.
      Q=Q+1
74    CONTINUE
73    CONTINUE
```

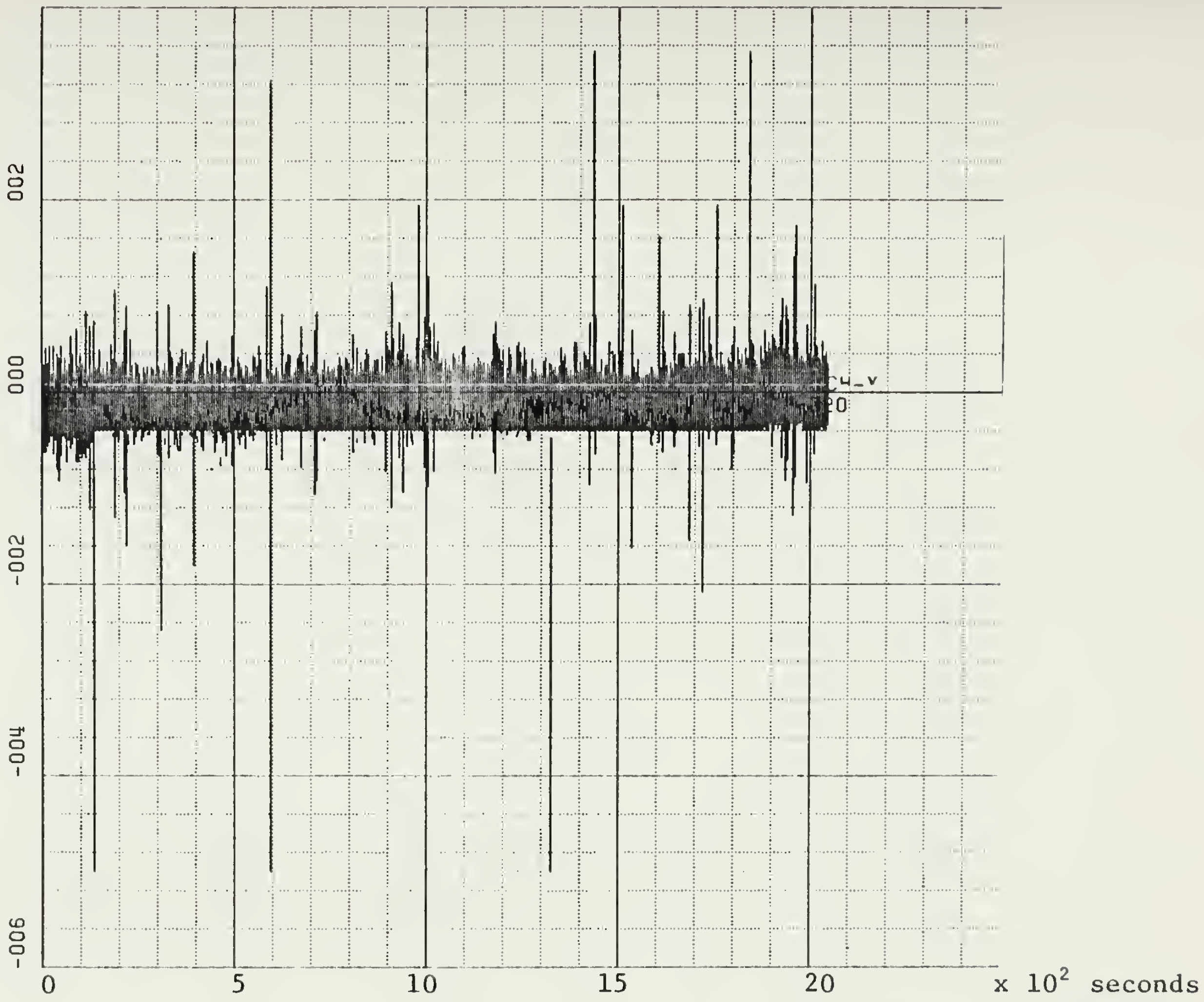

Figure 3.1. X Coil Voltage, 17 August 82, 1302-1336 Local. Amplitude (volts : 2 units/in) vs. Time (seconds : 500 units/in)

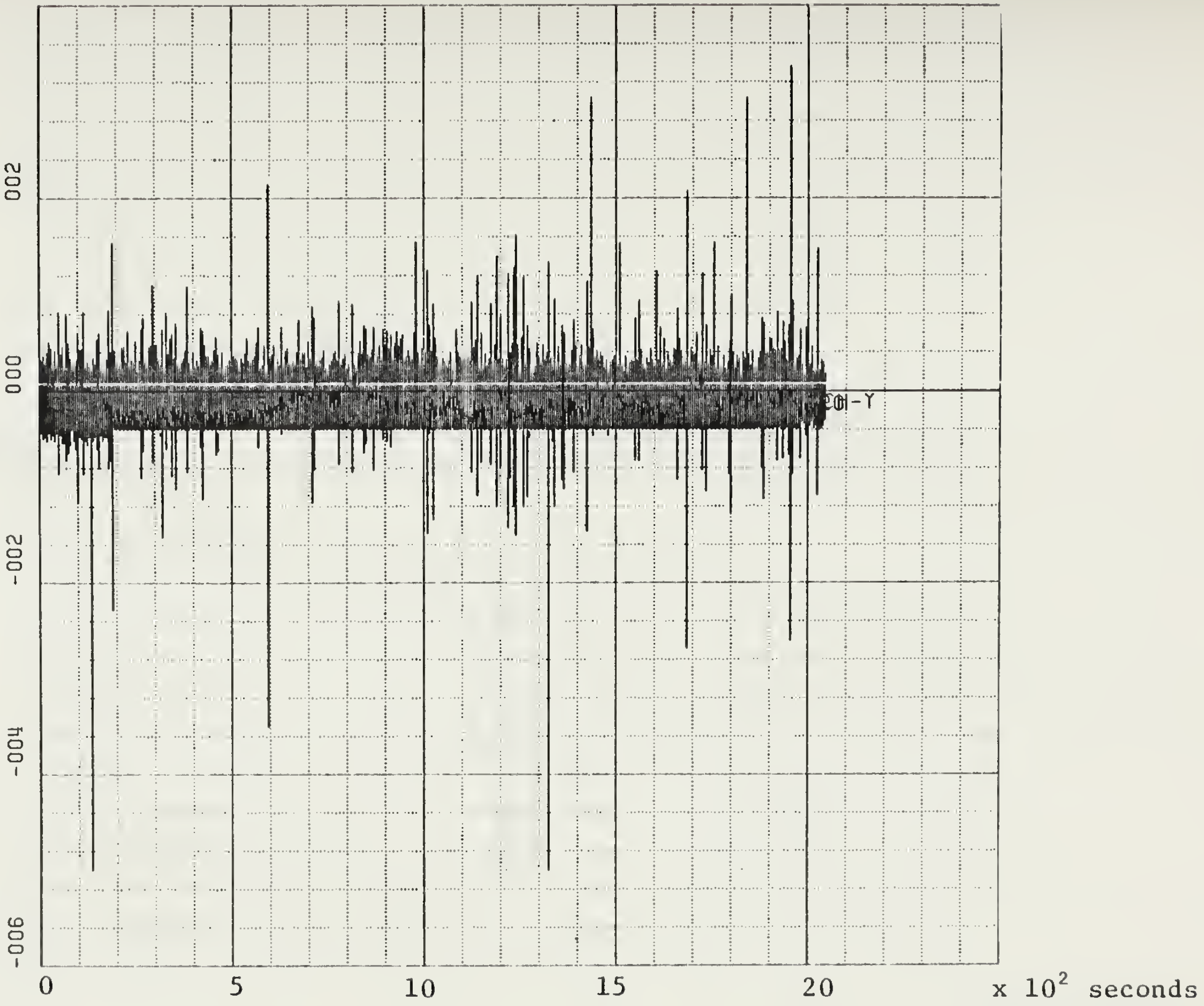

Figure 3.2. Y Coil Voltage, 17 August 82, 1302-1336 Local. Amplitude (volts : 2 units/in) vs. Time (seconds : 500 units/in)

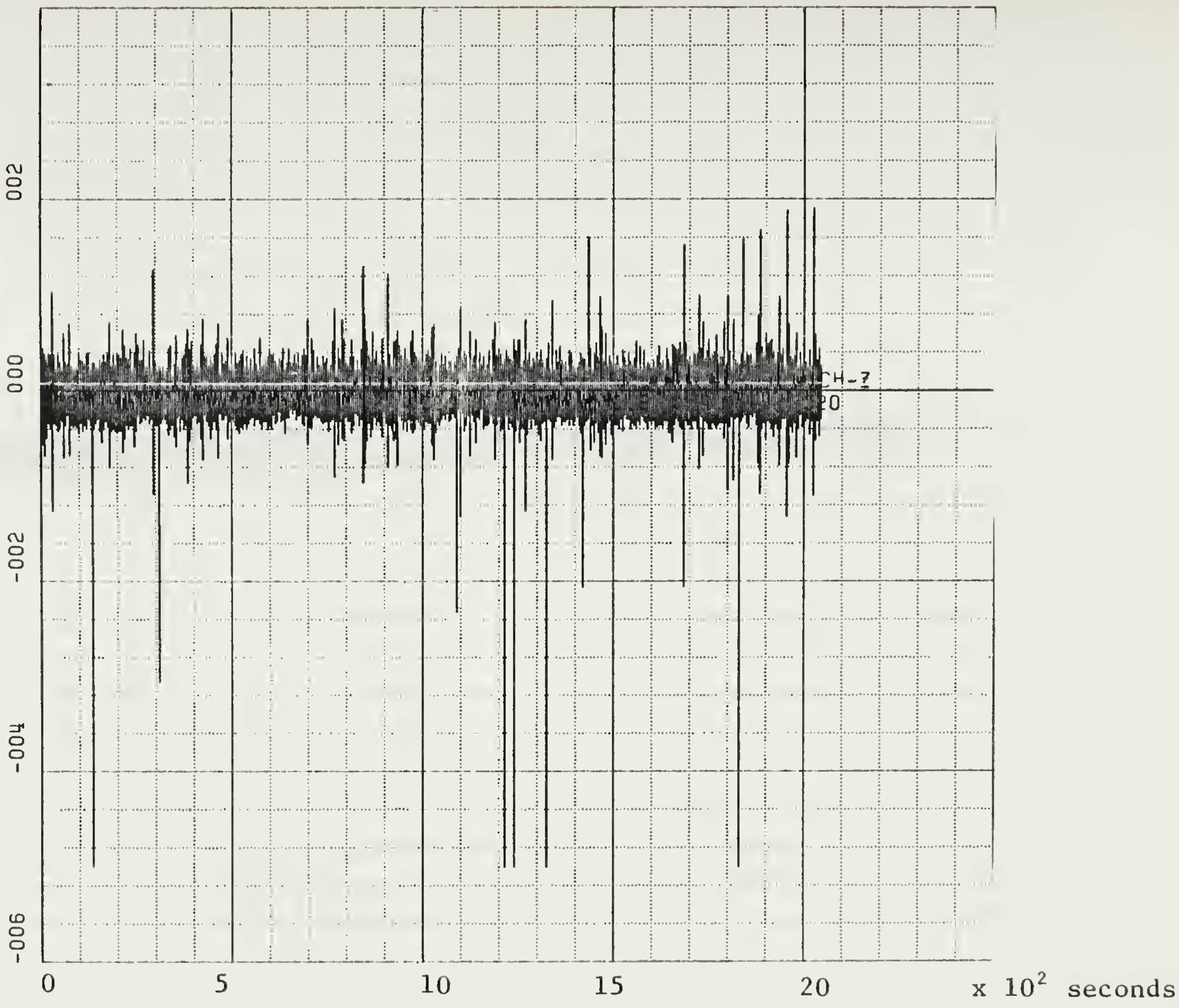

Figure 3.3. Z Coil Voltage, 17 August 82, 1302-1336 Local.
Amplitude (volts : 2 units/in) vs. Time (seconds : 500 units/in)

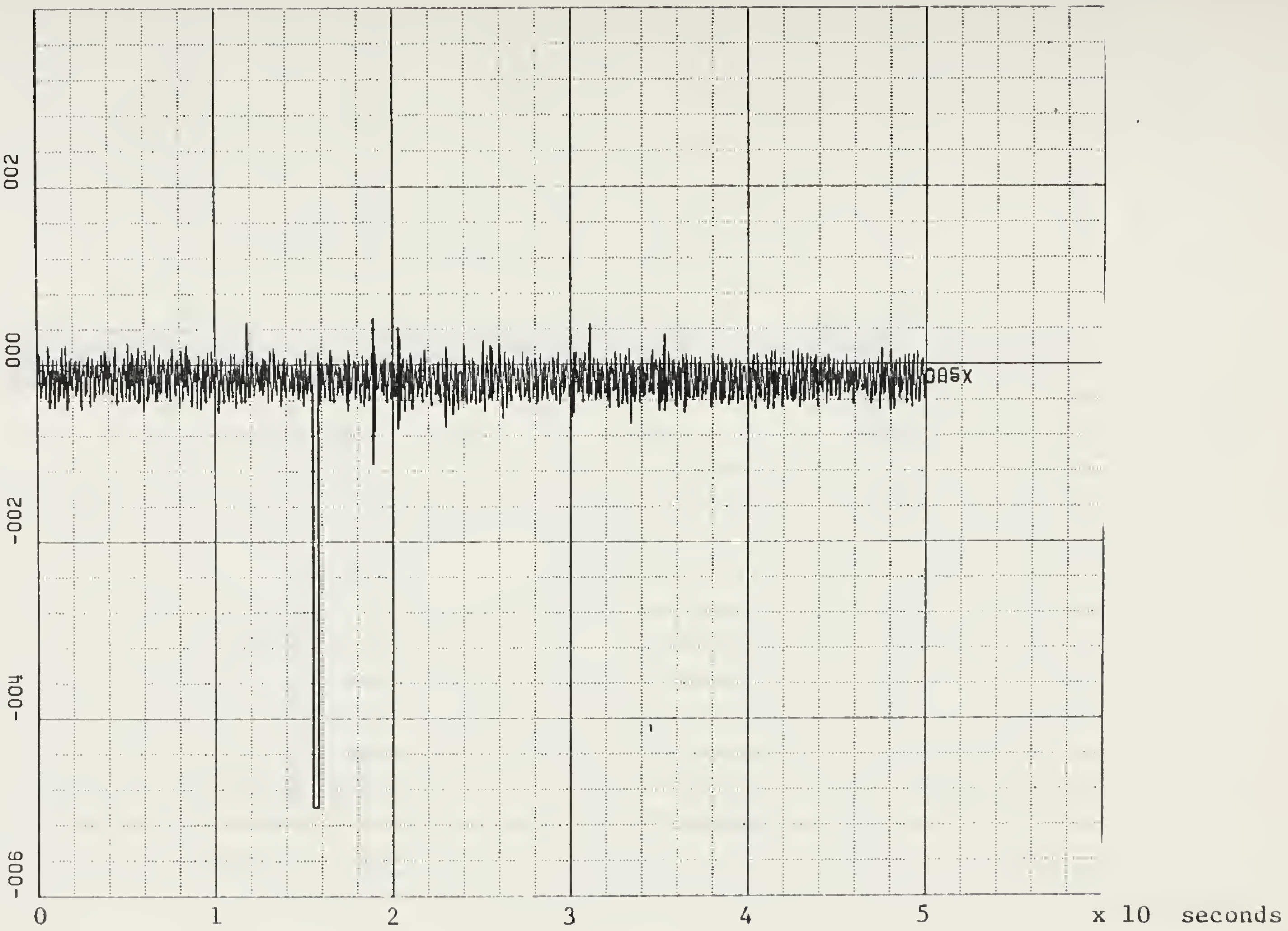

Figure 3.4. X-Coil Voltage, 17 August 82, 1322-1323 Local.
Amplitude (Volts: 2 units/in) vs. Time (seconds : 10 units/in)

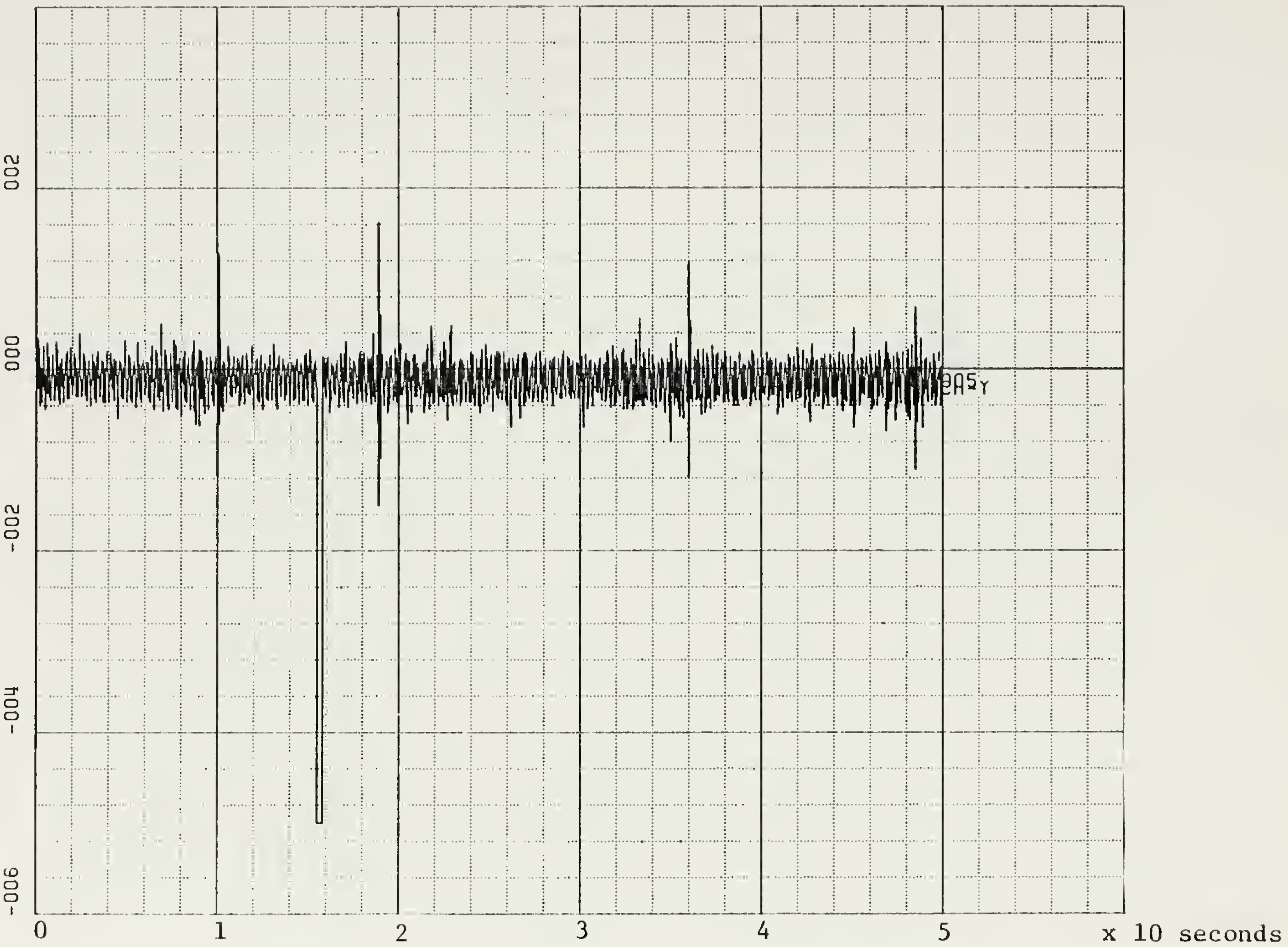

Figure 3.5. Y-Coil Voltage, 17 August 82, 1322-1323 Local.
Amplitude (volts : 2 units/in) vs. Time (seconds : 10 units/in)

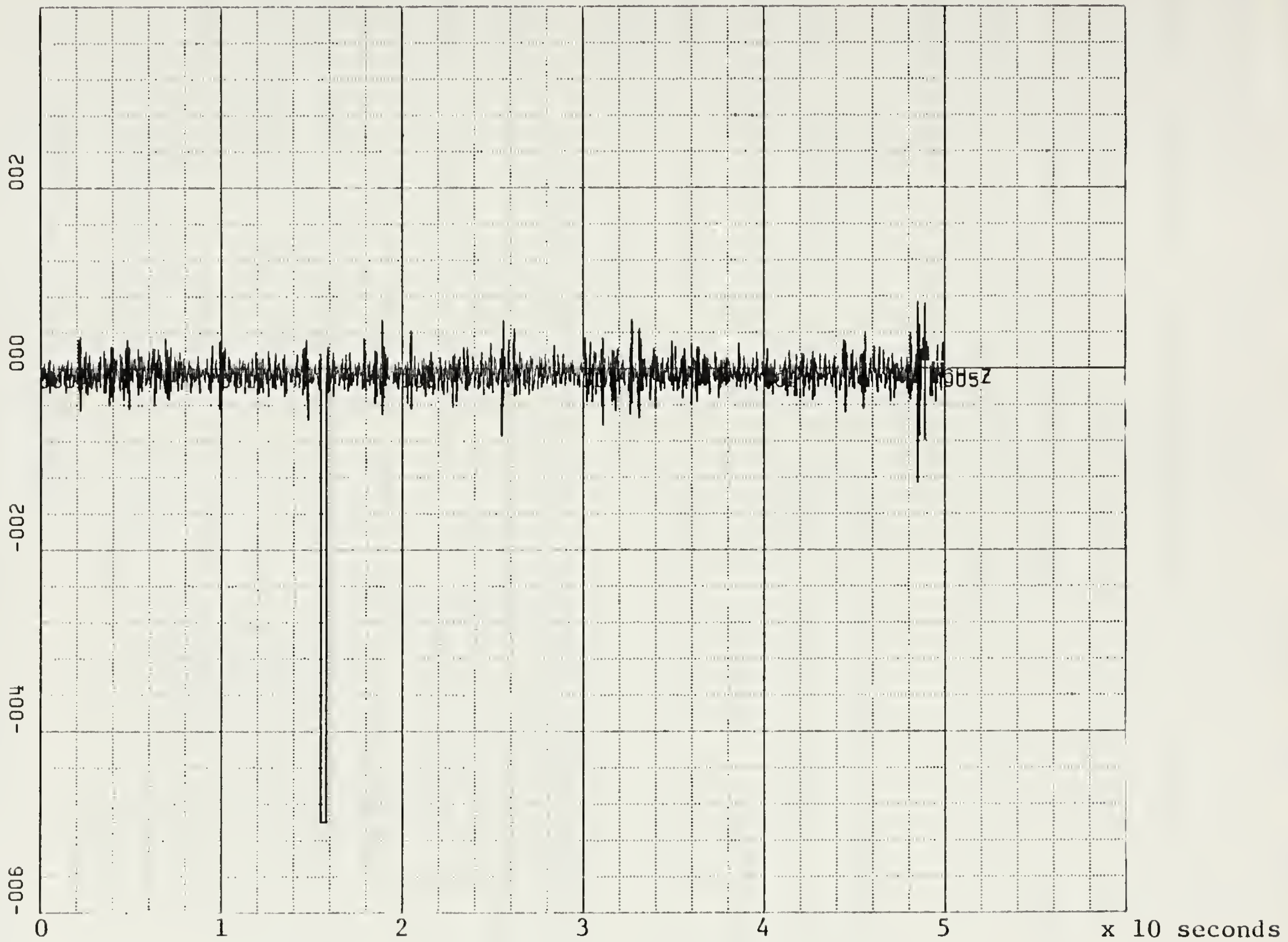

Figure 3.6. Z-Coil Voltage, 17 August 82, 1322-1323 Local.
Amplitude (volts : 2 units/in) vs. Time (seconds : 10 units/in)

seconds of data, the structure of the voltage spikes becomes apparent in Figures 3.4-3.6. The "square well" shape is characteristic of PCM dropouts or instances during the PCM to digital conversion synchronization is lost between the tape recorder containing the PCM tape and the decoding unit. We do not know whether PCM dropouts always occur on all three channels, but current evidence suggests dropouts are simultanoues on all channels.

Figures 3.7-3.9 again show the first 34 minutes of GMDT 11 only smoothed by the 144 point running average. The smoothing algorithm removes the 60 hertz alising. The PCM dropouts appear as "glitches" in the otherwise quasi sinusoid characteristic of a micropulsation.

We should note that the unusually large amount of hash present between 2 hertz and 10 hertz in the PSD's and the average slope of the PSD curve for those frequencies may in part be due to the PCM dropouts that occur on the tapes. A "deglitching" algorithm could be developed to remove the sudden large amplitude structures injected by the system into the voltage data if hardware modifications fail.

B. TIME SERIES MAGNETIC FIELD DATA

1. Magnetic Field Software

The time series magnetic field software is basically the same as that which produces the PSD's, etc. [Ref. 1 and Ref. 3]. The differences begin after the forward Fourier transform and the application of the transfer function. We

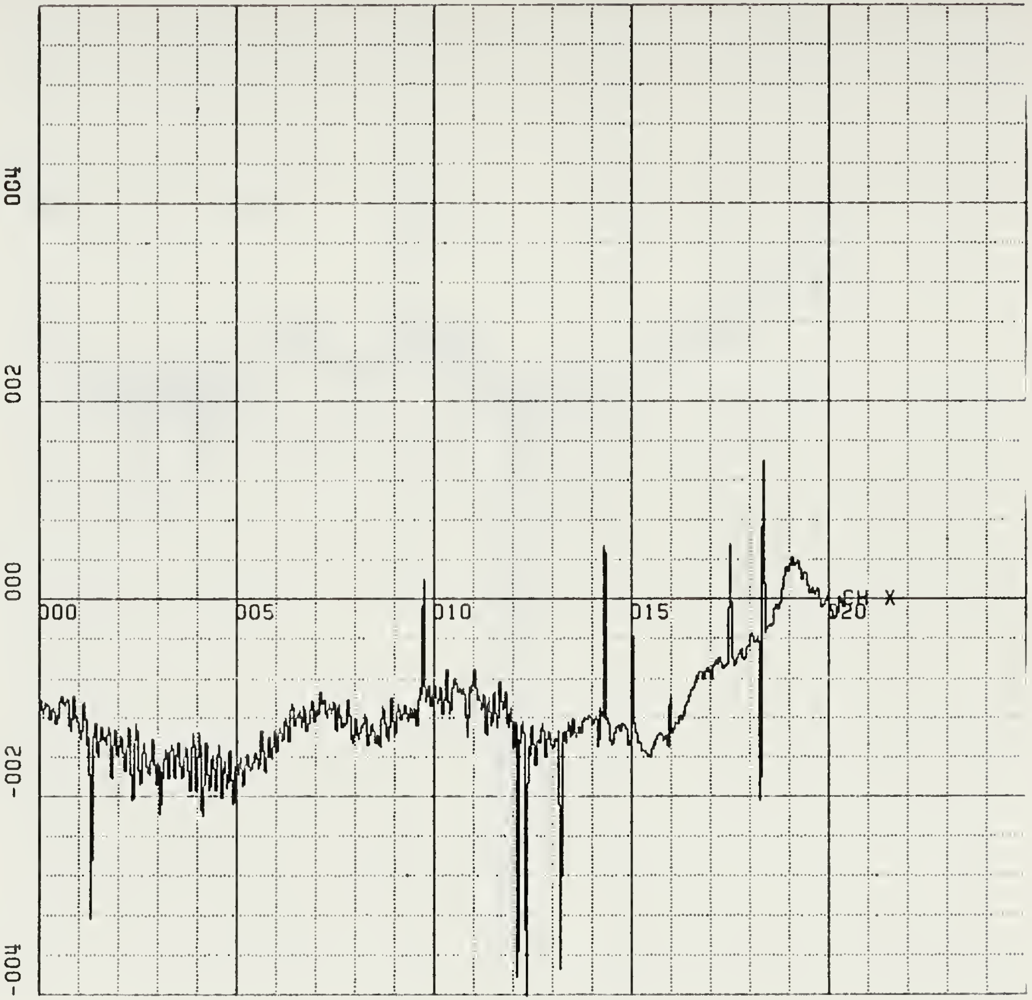

Figure 3.7. X Coil Voltage, 17 August 82, 1302-1336 Local.
Amplitude (volts : 0.2 units/in) vs. Time (seconds : 500 units/in)

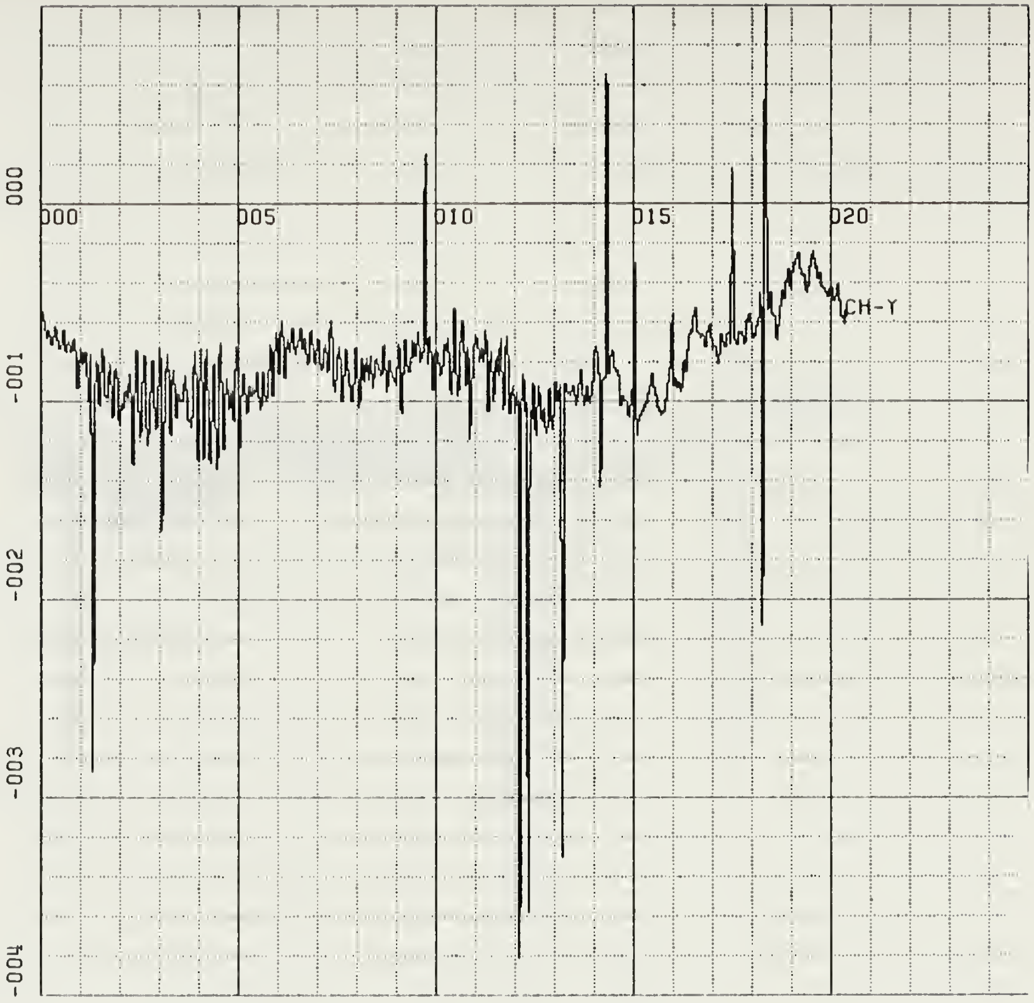

Figure 3.8. Y Coil Voltage, 17 August 82, 1302-1336 Local.
Amplitude (volts : 0.1 units/in) vs. Time (seconds : 500 units/in)

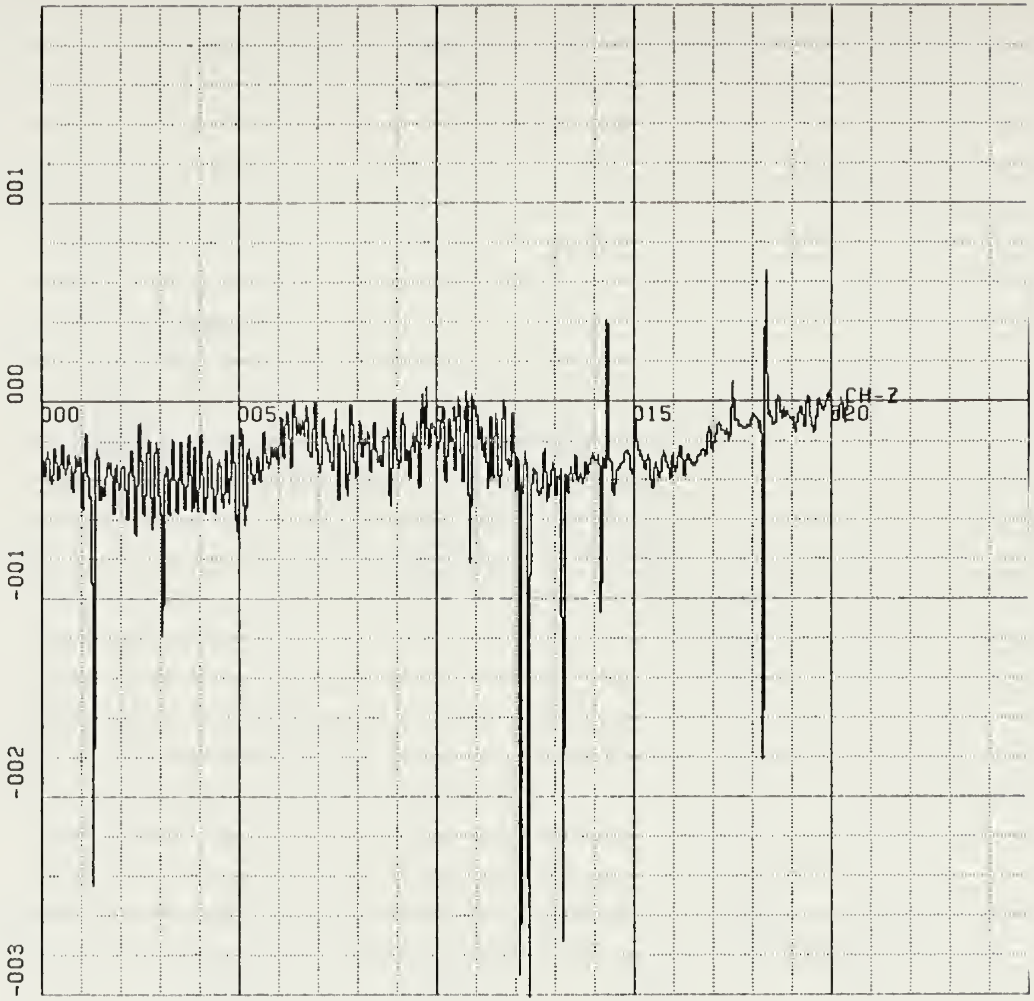

Figure 3.9. Z Coil Voltage, 17 August 82, 1302-1336 Local.
Amplitude (volts : 0.1 units/in) vs. Time (seconds :500 units/in)

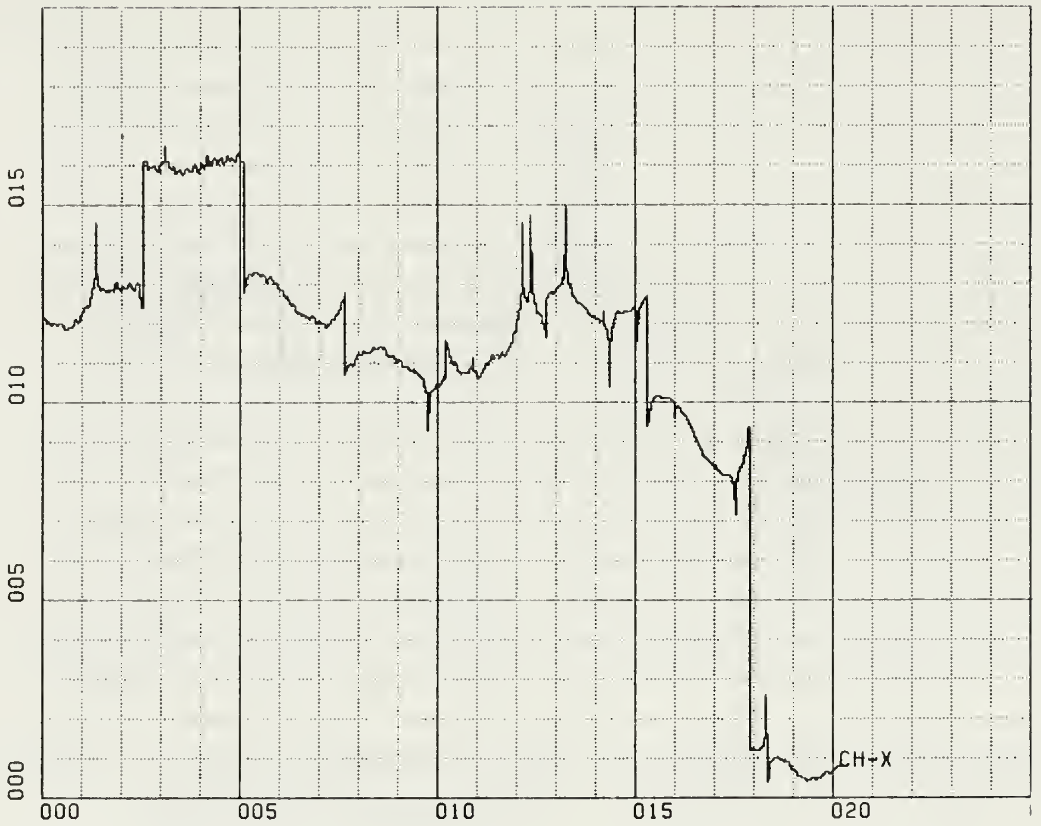

Figure 3.10a. X-Coil Magnetic Field, 17 August 82, 1302-1336 Local. Amplitude (nanoteslas : 5 units/in) vs. Time (seconds : 500 units/in) 8 point smoothing

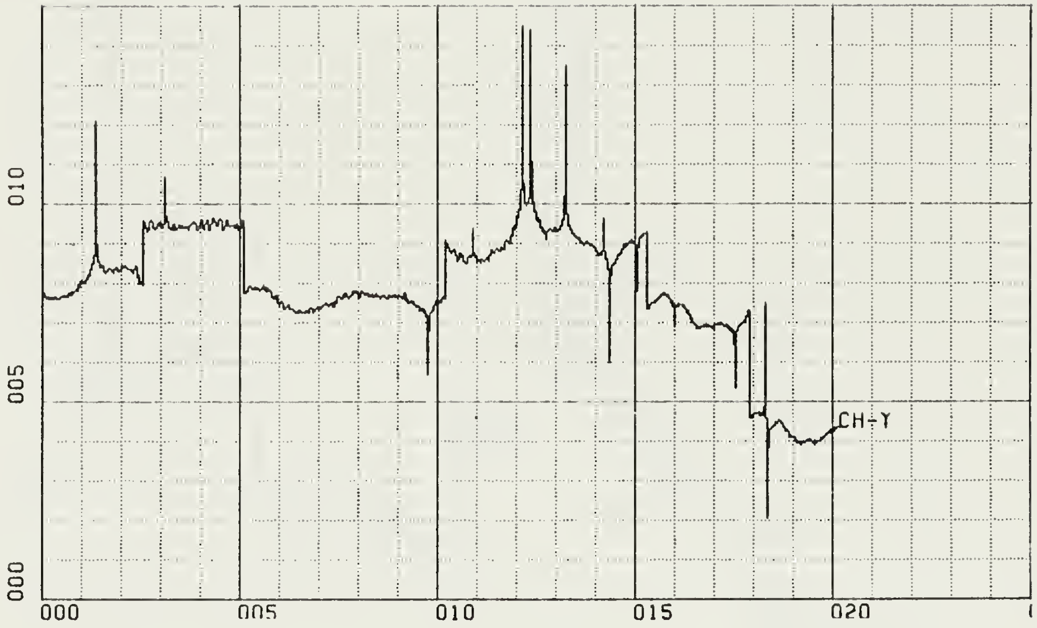

Figure 3.11a. Y-Coil Magnetic Field, 17 August 82, 1302-1336 Local.
Amplitude (nanoteslas : 5 units/in) vs. Time (seconds : 500 units/in)
8 point smoothing

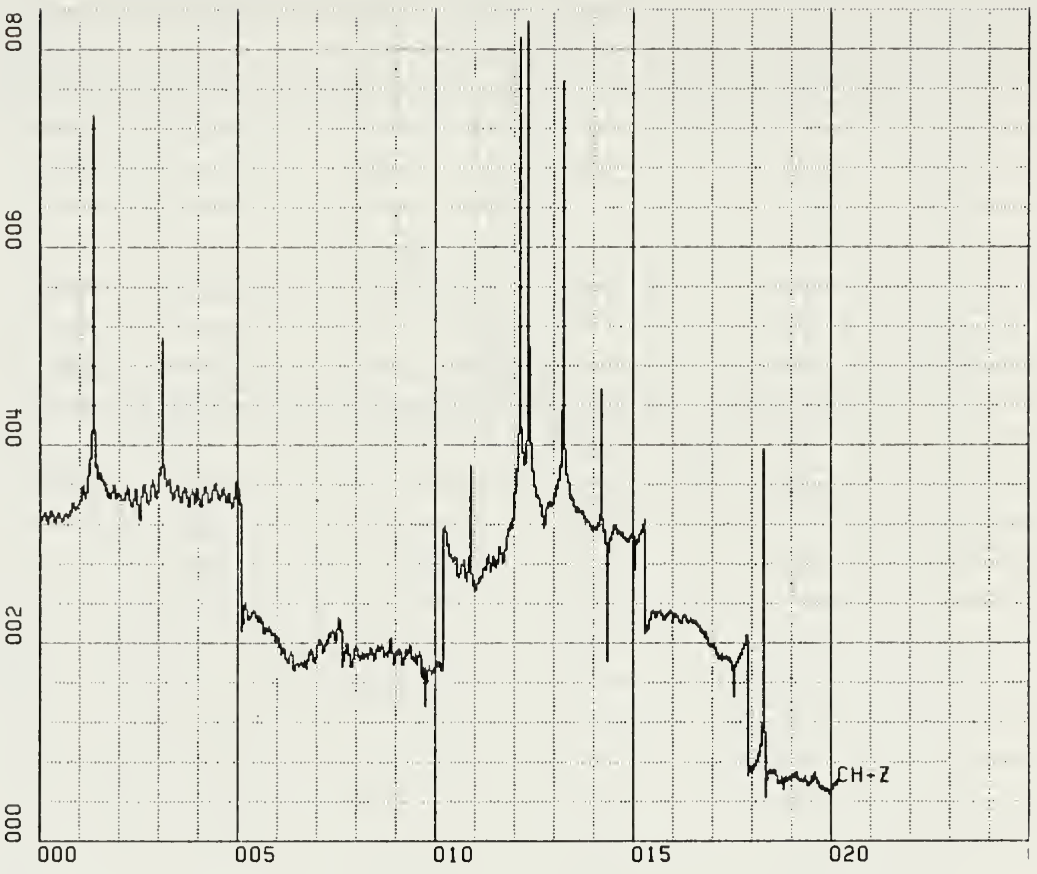

Figure 3.12a. Z-Coil Magnetic Field, 17 August 82, 1302-1336 Local. Amplitude (nanoteslas : 2 units/in) vs. Time (seconds : 500 units/in) 8 point smoothing

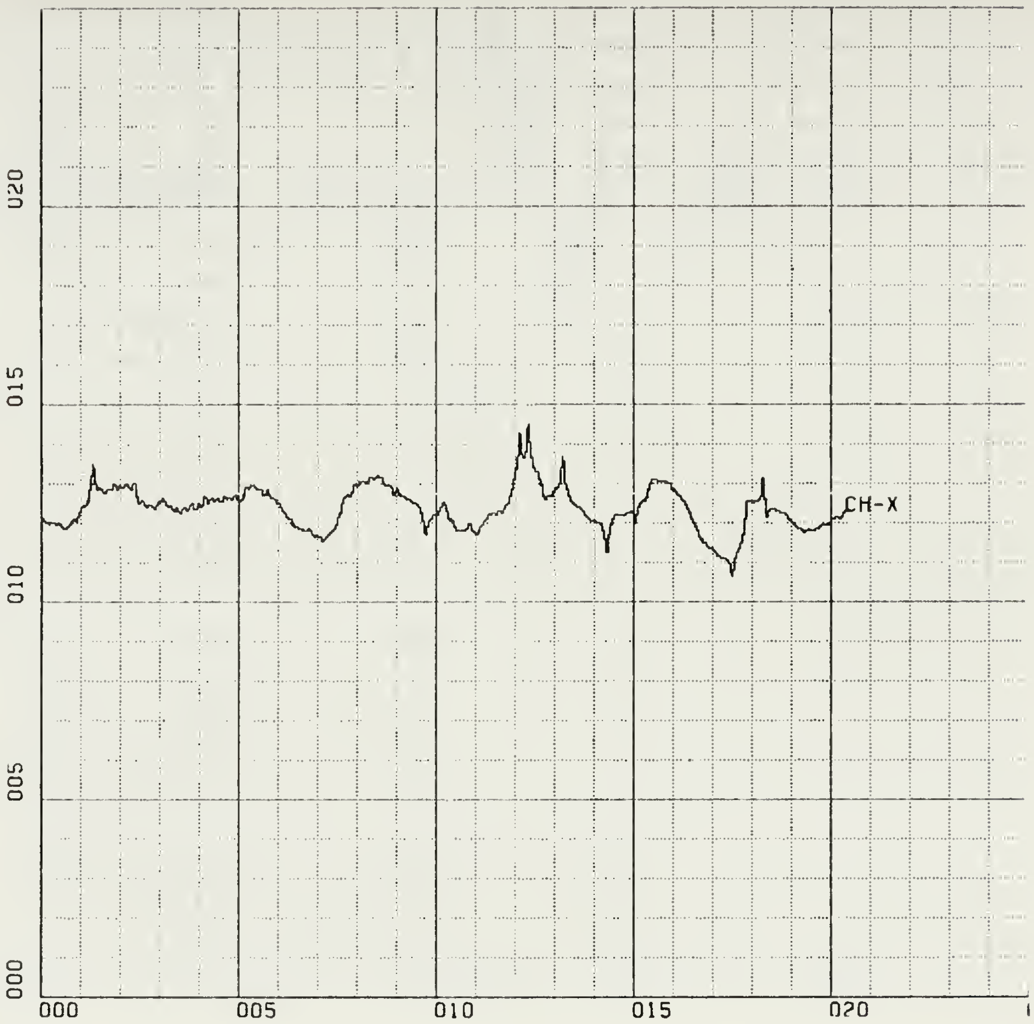

Figure 3.10b. X Coil Magnetic Field, 17 August 82, 1302-1336 Local.
Amplitude (nanoteslas : 5 units/in) vs. Time (seconds : 500 units/in)
144 point smoothing

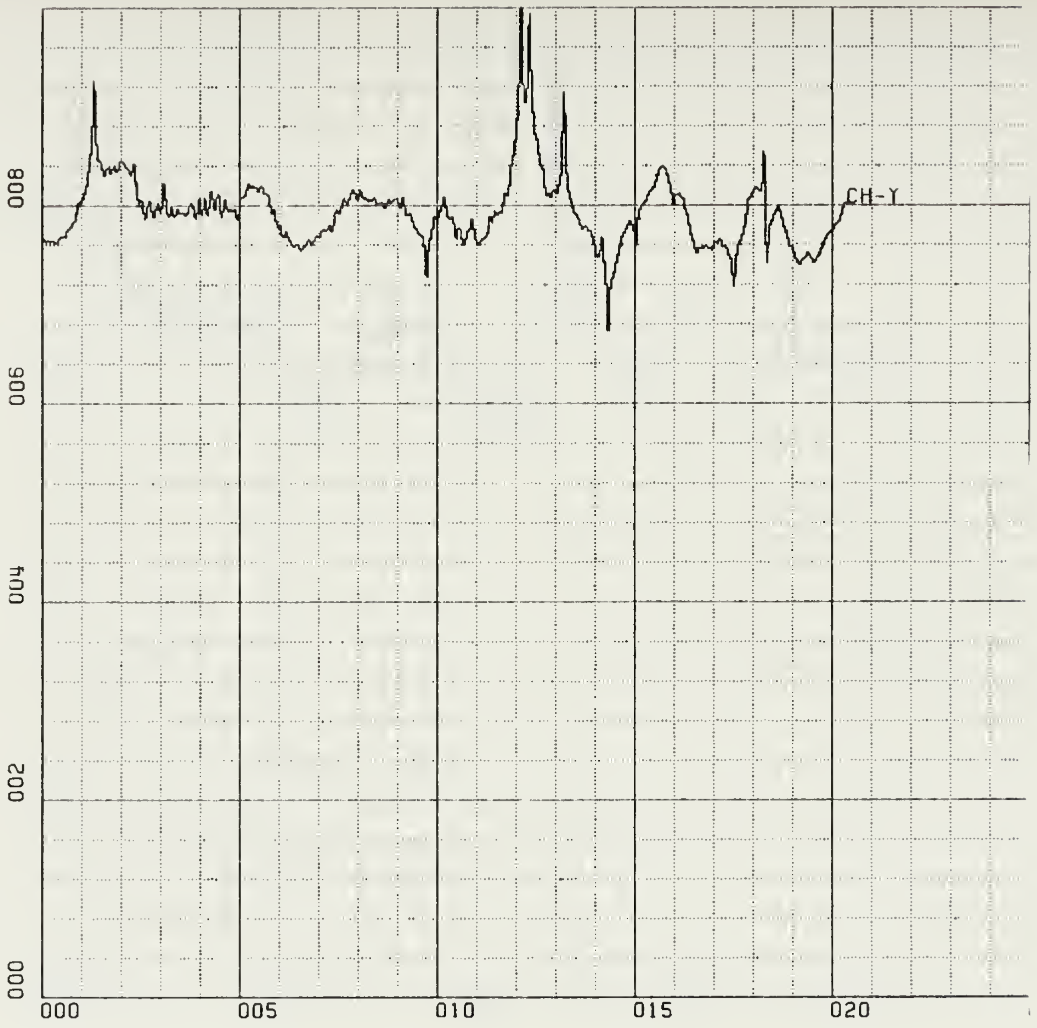

Figure 3.11b. Y Coil Magnetic Field, 17 August 82, 1302-1336 Local.
Amplitude (nanoteslas : 1 unit/in) vs. Time (seconds : 500 units/in)
144 point smoothing

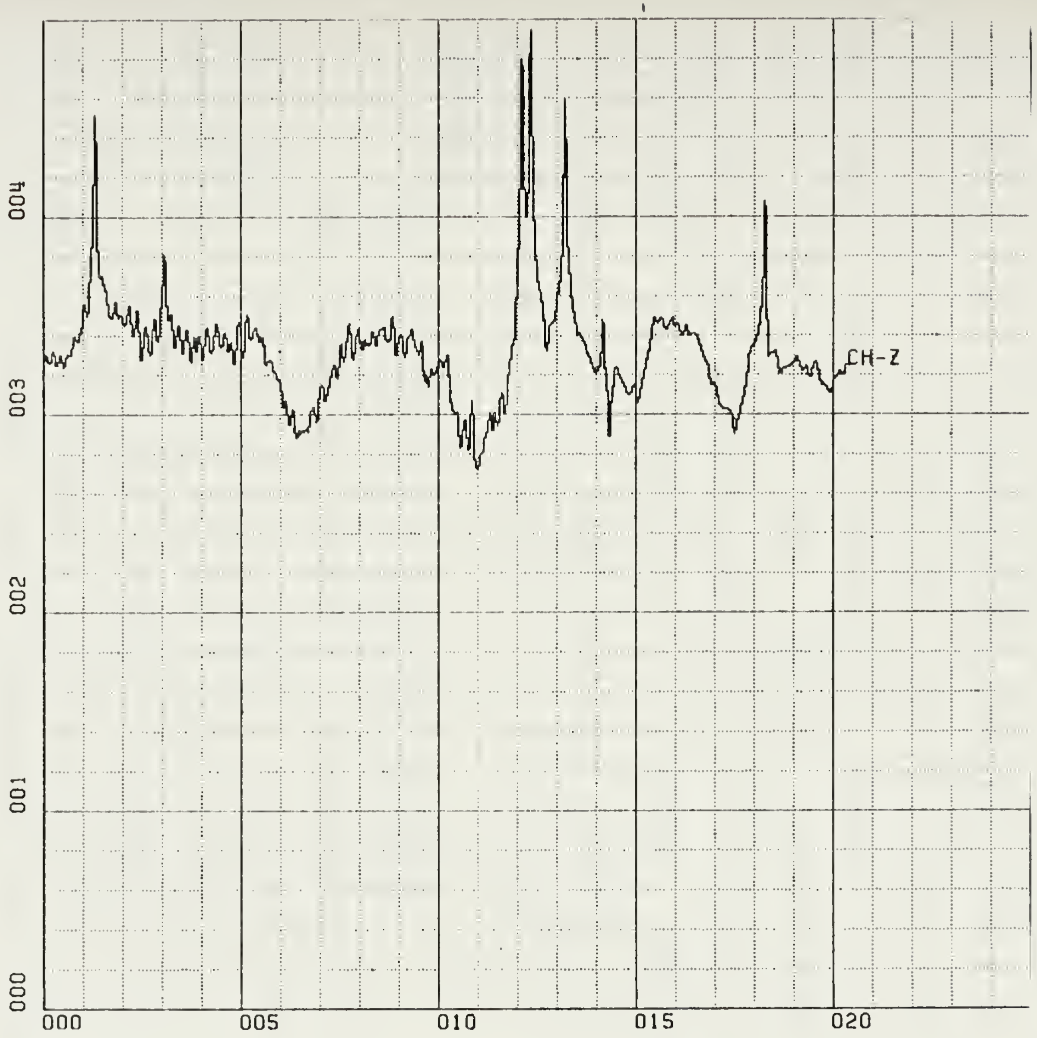

Figure 3.12b. Z Coil Magnetic Field, 17 August 82, 1302-1336 Local, Amplitude (nanoteslas : 1 unit/in) vs. Time (seconds : 500 units/in) 144 point smoothing

should note that the transfer function as designed ignores phase information since it is just a least squares fit to data like that of Figure 2.2. Once the transfer function is applied, the reverse transform is performed. We obtain the complex absolute values of the magnetic field data (in nanoteslas) and place the data in new real arrays. To insure that there are no discontinuities between blocks of data, Figures 3.10a, 3.11a and 3.12a, all the blocks are connected to the first by adding or subtracting a constant to each element, Figures 3.10b, 3.11b, 3.12b. The data now undergoes the same 144 point double running average as the voltage to bring out fluctuations with periods of 10-45 seconds. Again DRAWP is used to plot the data. The computer program LVFTC1 produces the smoothed magnetic field plots. It is provided in Appendix C.

2. Smoothed Magnetic Field Data Analysis

Again looking at the first 34 minutes of digital data tape GMDT 11, we see in the magnetic field data the same exceptional structures as seen in the voltage data, Figures 3.10-3.12. The glitches, however, do highlight one problem rather well. From Figures 3.7-3.9 we note that positive voltage spikes produce negative magnetic field spikes. This would indicate a pi phase shift is introduced either in the transfer functions or in the digital Fourier transform. After investigating another digital tape GMDT 3A, 18 August 82, 0121-0251 local, we see another behavior. Figures 3.13-3.15

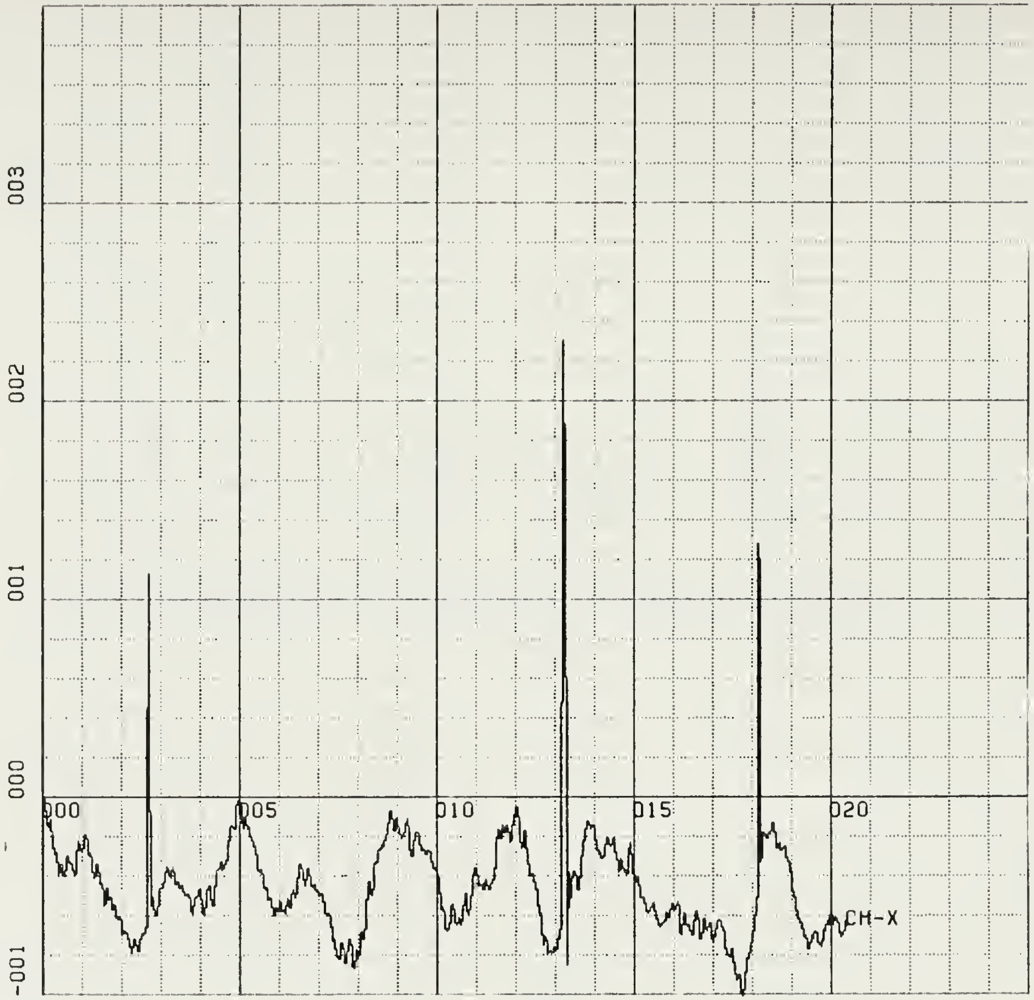

Figure 3.13. X Coil Voltage, 17 August 82, 2241-2315 Local.
Amplitude (volts : 0.1units/in) vs. Time (seconds : 500 units/in)

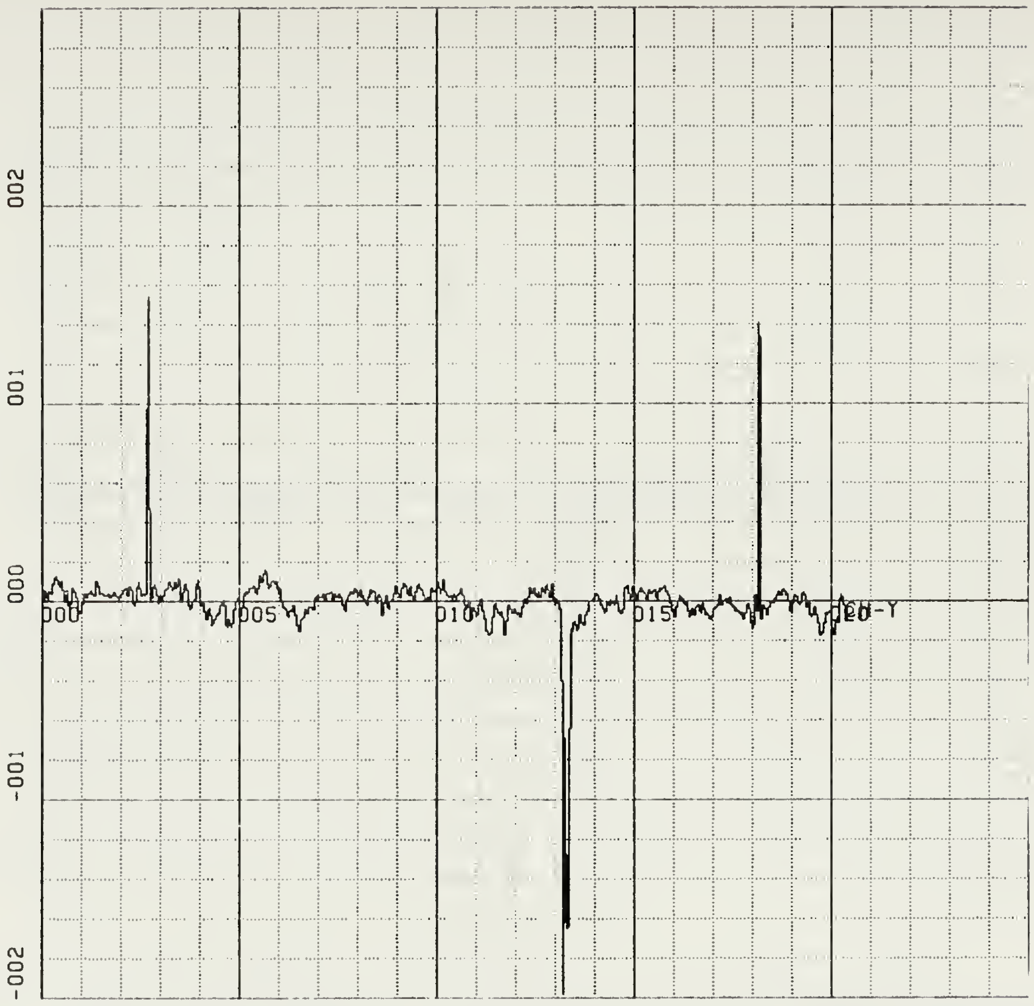

Figure 3.14. Y Coil Voltage, 17 Voltage 82, 2241-2315 Local.
Amplitude (volts : 0.1 units/in) vs. Time (seconds : 500 units/in)

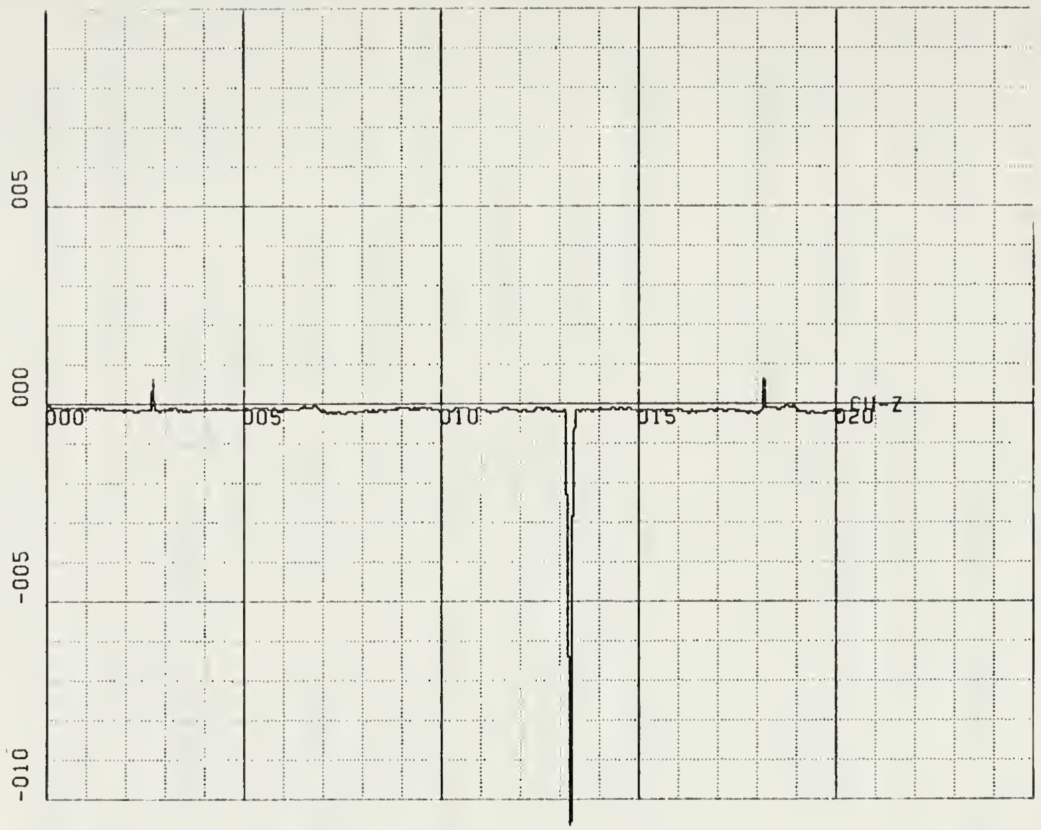

Figure 3.15. Z Coil Voltage, 17 August 82, 2241-2315 Local.
Amplitude (volts : 0.5 units/in) vs. Time (seconds : 500 units/in)

are the smoothed voltages for the first 34 minutes of data on GMDT3A after a one minute tape advance. Figures 3.16-3.18 are the smoothed magnetic fields for the same time period. The X-coil voltages show three positive spikes while the X-coil magnetic field shows three negative spikes. This supports the theory of a pi phase shift. However, the Y-coil voltage shows two positive spikes and one negative spike, while the Y-coil magnetic field has three positive spikes. Thus it appears we have a rather arbitrary phase problem that may find its origin in the transfer functions that do not maintain the correct phase.

From Figures 3.16-3.18 we note exceptional features that do not correspond to voltage spikes. The exceptional features are separated by time periods of 256 seconds which is the size of the blocks analyzed. These features persist with the data block connection scheme and 144 point smoothing. Their origin is not understood. Some data blocks look like Figure 3.19 with the end points having about the same value. However, some have end points as illustrated in Figure 3.20. The varying end point values are also shown in Figures 3.10a, 3.11a and 3.12a. This may be a source of the large amount of hash between 2 hertz and 10 hertz seen in the PSD's.

After looking at the magnetic field data it was obvious a validation experiment was needed for the sensing system and software.

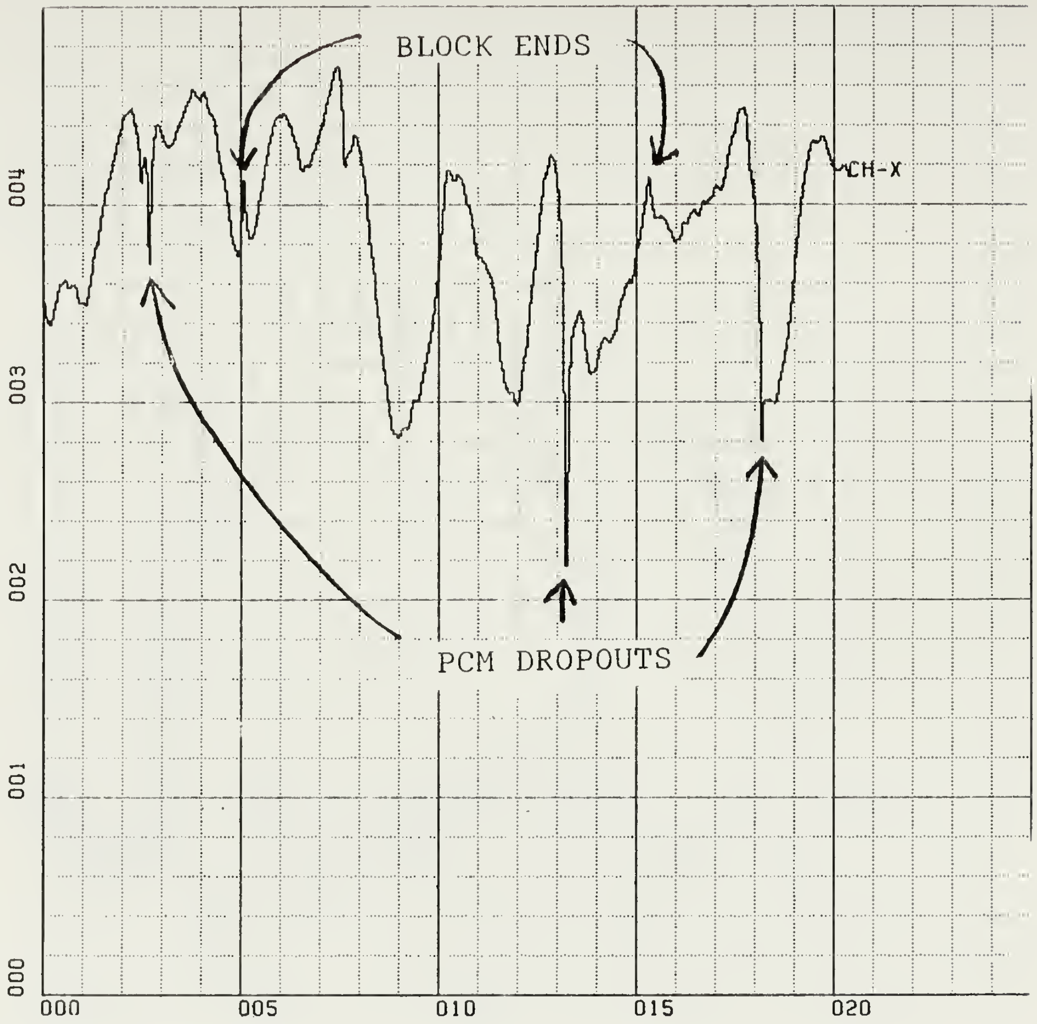

Figure 3.16. X Coil Magnetic Field, 17 August 82, 2241-2315, Local. Amplitude (nanoteslas : 1 unit/in) vs. Time (seconds : 500 units/in)

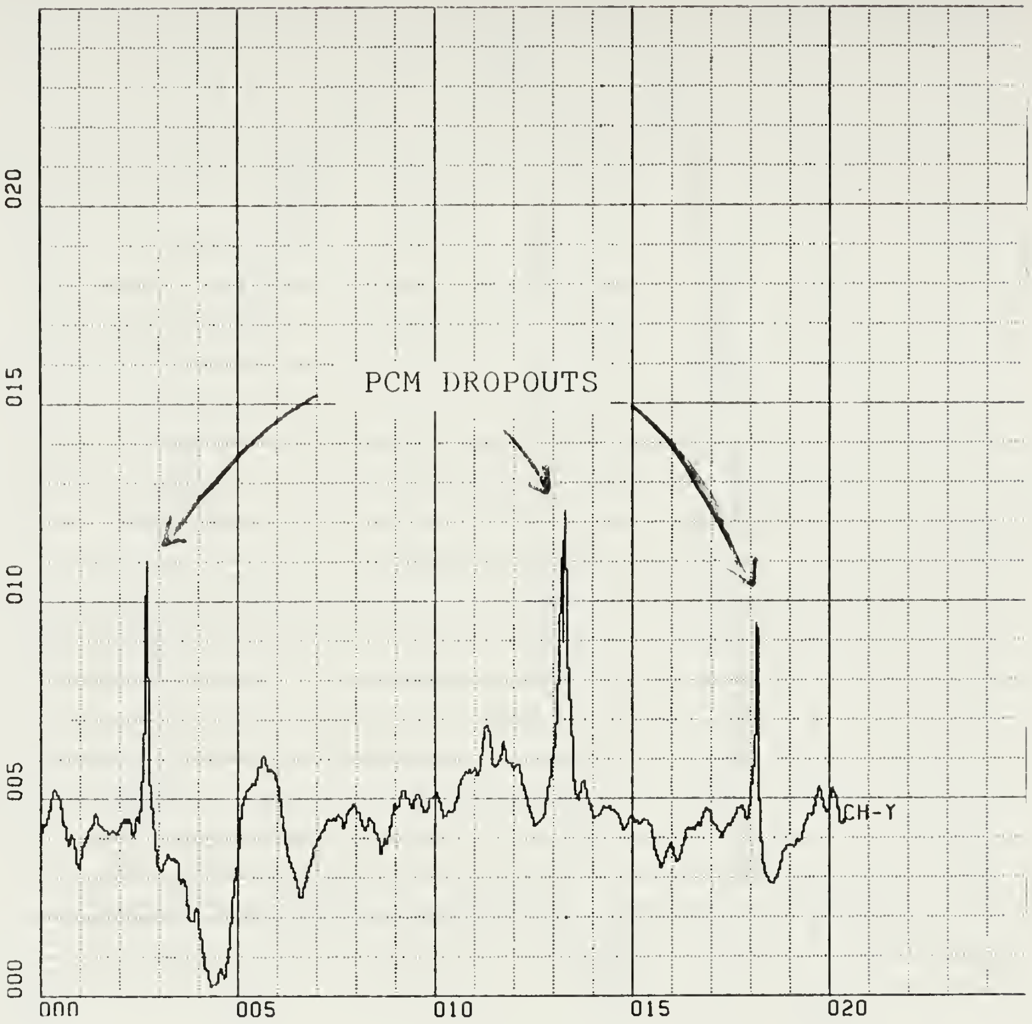

Figure 3.17. Y Coil Magnetic Field, 17 August 82, 2241-2315 Local. Amplitude (nanoteslas : 0.5 units/in) vs. Time (seconds : 500 units/in)

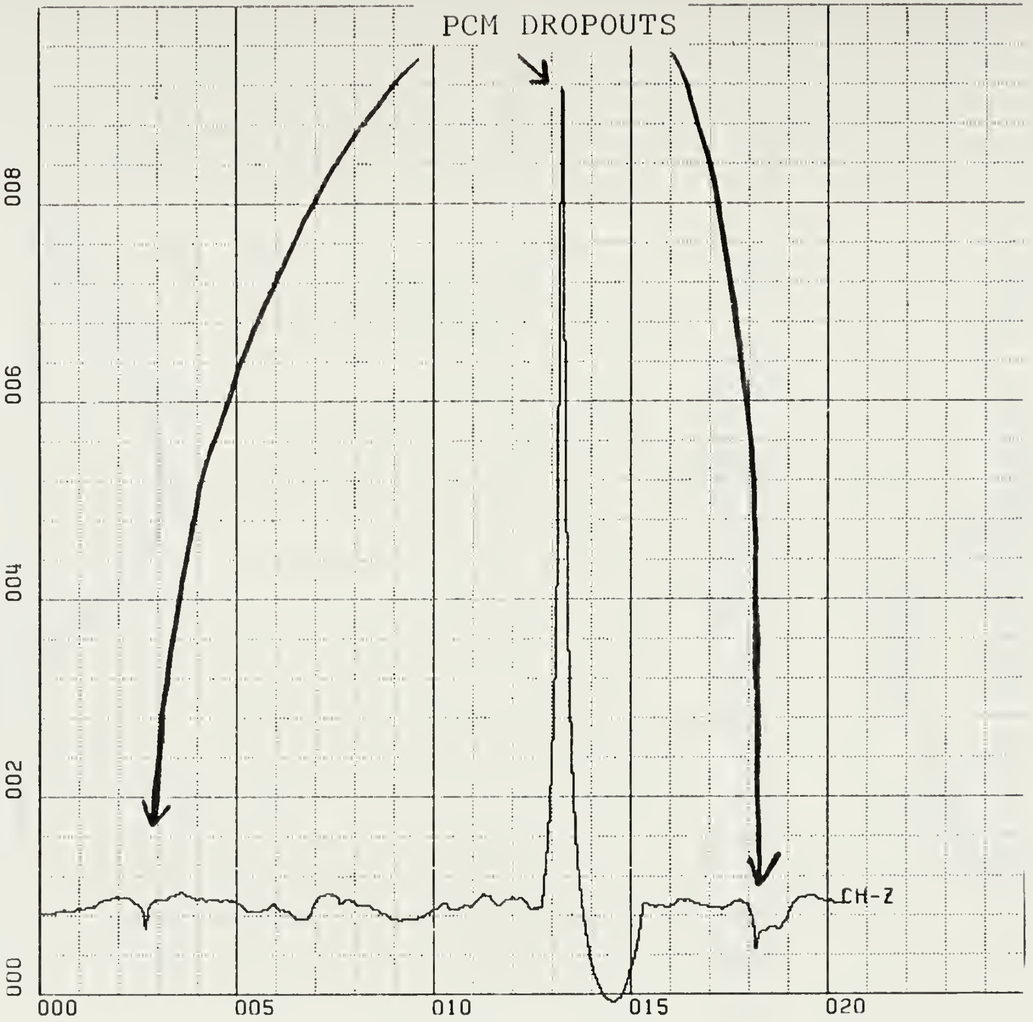

Figure 3.18. Z Coil Magnetic Field, 17 August 82, 2241-2315 Local. Amplitude (nanoteslas : 2 units/in) vs. Time (seconds : 500 units/in)

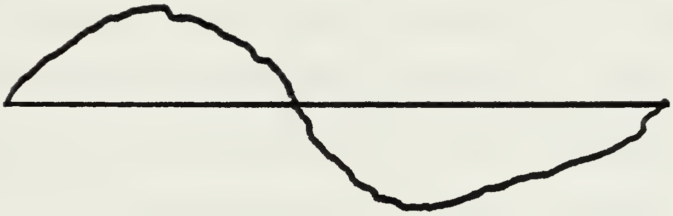

Figure 3.19. One Frame of Data with End Points Having the Same Value

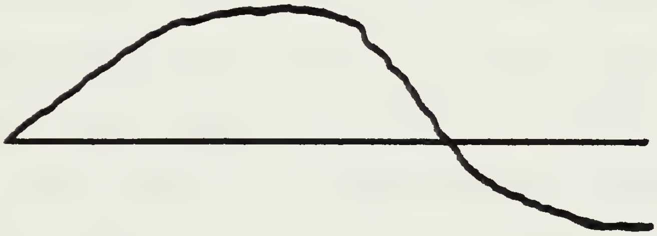

Figure 3.20. One Frame of Data with End Points Having Different Values

IV. SYSTEM AND SOFTWARE VALIDATION

A. EXPERIMENTAL APPARATUS

The inconsistencies in phase between the time series voltage and magnetic field plots prompted an experiment to validate the sensing system and software. The sensing apparatus consisted of the X-coil and a Schoenstadt fluxgate magnetometer. The sensing axis of both sensors were horizontal and oriented North-South. Figure 4.1 shows the test set-up. Instead of an on axis arrangement, the set-up shown was used because of limited resources. The fluxgate magnetometer is closer to the source since it has less sensitivity at the frequency of interest than the coils. Recorded on the usual X-channel was the output from the X-coil. The Y-channel contained data from the coil after passing through an additional Krohn-Hite model 3321 lowpass filter with a 10 hertz cutoff. On the Z-channel was the output from the fluxgate magnetometer. All three channels were recorded simultaneously and a 64 sample/second sample rate was used. An on-site chart recorder monitored the fluxgate and double filtered coil voltage output real time. The experiment produced two digital data tapes each approximately 46 minutes in length denoted GMTT1A and GMTT1B.

Artificial magnetic fields were introduced into the region by applying sinusoidal currents from a Wavetek signal generator to a cylinder (diameter = 0.13m) wrapped with 150 turns of wire. Location of the source is noted in Figure 4.1. The

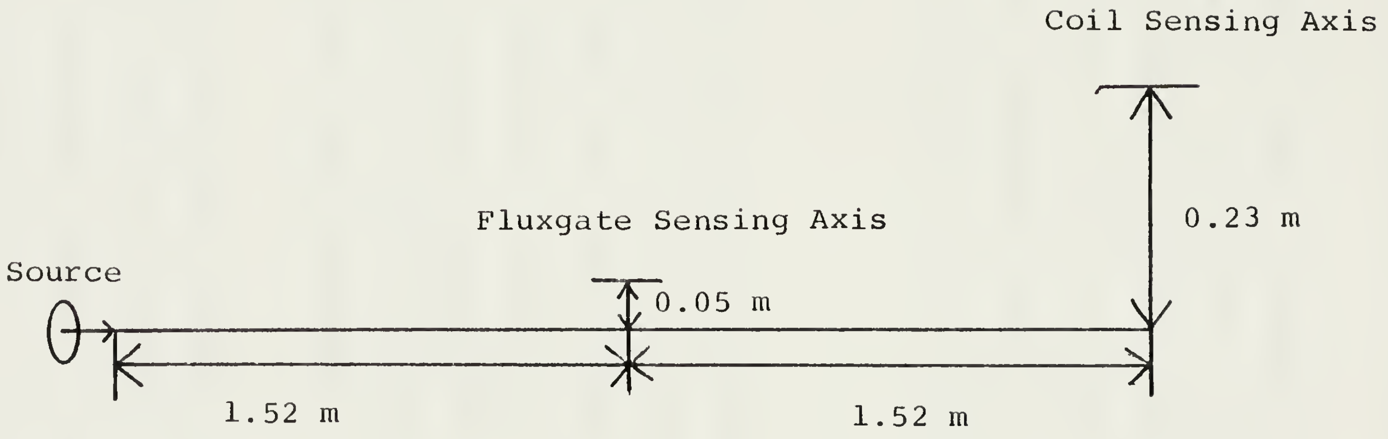

Figure 4.1. Test Arrangement

applied sinusoidal currents varied in frequency from 0.005 hertz to 10 hertz. For each frequency, two magnitude currents were applied to the source to demonstrate a linear response with amplitude.

The fluxgate magnetometer output is correct in phase and amplitude to at least 1 hertz. The transfer function between voltage and magnetic field for the fluxgate magnetometer is a constant of 10 nanoteslas/volt. Thus the fluxgate provides an excellent check for the coil transfer functions, the RD data stripping subroutine and the digital fourier transform.

B. EXPERIMENT RESULTS

1. Voltage

From the real time chart record of voltage for the fluxgate and double filtered coil, we can check the computer generated voltages using VOLTR and VOLTS. Table 4.1 shows the chart record and computer generated voltages for the fluxgate and double filtered coil at various frequencies. Only the large amplitude oscillations are measured for the double filtered coil because of poor signal-to-noise, for the small amplitude oscillations.

Table 4.1 shows good agreement between the chart record and computer output for the double filtered coil. However, the fluxgate magnetometer voltages undergo a constant transformation of 0.831 from chart record to computer plot. This may be explained by a problem in the data stripping

Table 4.1. Coil and Fluxgate Voltage

FREQUENCY (HZ)	CHART RECORD VOLTAGE (V)			COMPUTER GENERATED VOLTAGE (V)		
	FLUXGATE		COIL	FLUXGATE		COIL
	Large Amplitude Oscillation	Small Amplitude Oscillation	Large Amplitude Oscillation	Large Amplitude Oscillation	Small Amplitude Oscillation	Large Amplitude Oscillation
0.1	2.45	0.78	0.90	2.00	0.60	0.90
0.09	2.45	0.80	0.76	1.98	0.60	0.83
0.08	2.45	0.78	0.69	2.00	0.60	0.70
0.07	2.44	0.70	0.66	2.00	0.60	0.68
0.06	2.46	0.77	0.50	1.97	0.60	0.50
0.05	2.45	0.79	0.40	2.20	0.75	0.40
0.04	2.41	0.78	0.40	2.15	0.70	0.37
0.03	2.50	0.82	0.30	2.02	0.65	0.33
0.02	2.50	0.76	0.20	2.03	0.60	0.31
0.01	2.50	0.78		1.96	0.57	

Double filtered coil and fluxgate magnetometer voltages, real time and computer generated.

algorithm. The present agreement between the chart record and computer generated voltages is shown in Table 4.2.

Another more serious problem became obvious during the examination of the computer generated voltage plots. For approximately the first 20 minutes of data recording the fluxgate magnetometer was not connected to the PCM board. Figures 4.2-4.4 show the two respective sensing devices. Figures 4.2 and 4.3 both contain "real" signal while Figure 4.4 does not contain "real" signal until the amplitude discontinuity indicating connection of the fluxgate magnetometer to the PCM board. Figures 4.2-4.4 indicate that "pick-up" is occurring probably between the channels at the PCM board. The amplitude of the cross-talk voltage is about 0.15 volts peak-to-peak at the frequency of 0.1 hertz. The amplitude of the "real" signal on the double filtered coil is 0.29 volts at 0.1 hertz. Thus 51 percent of the "real" signal is coupled to the disconnected channel. Coupling between channels of this magnitude raises serious questions about the computer generated data, especially for coherence. Discovering the amount of the channel pick-up if the channel is loaded requires further experimentation.

Figures 4.5-4.7 show an interesting feature of the coil data versus fluxgate magnetometer data. On the channels containing the coil output we see noise on top of the signal. This noise is not present on the channel containing the fluxgate magnetometer data. Since all three channels passed

Table 4.2. Percent Agreement Between the Chart Record and Computer Generated Voltages

FREQUENCY (HZ)	FLUXGATE FIELD (%)		COIL FIELD (%)
	Large Amplitude Oscillation	Small Amplitude Oscillation	Large Amplitude Oscillation
0.1	87	74	100
0.09	87	72	94
0.08	87	76	99
0.07	87	84	98
0.06	87	84	100
0.05	87	97	100
0.04	87	93	92
0.03	87	84	94
0.02	87	80	69
0.01	86	80	

0.1 Hz with 60 Hz Aliasing

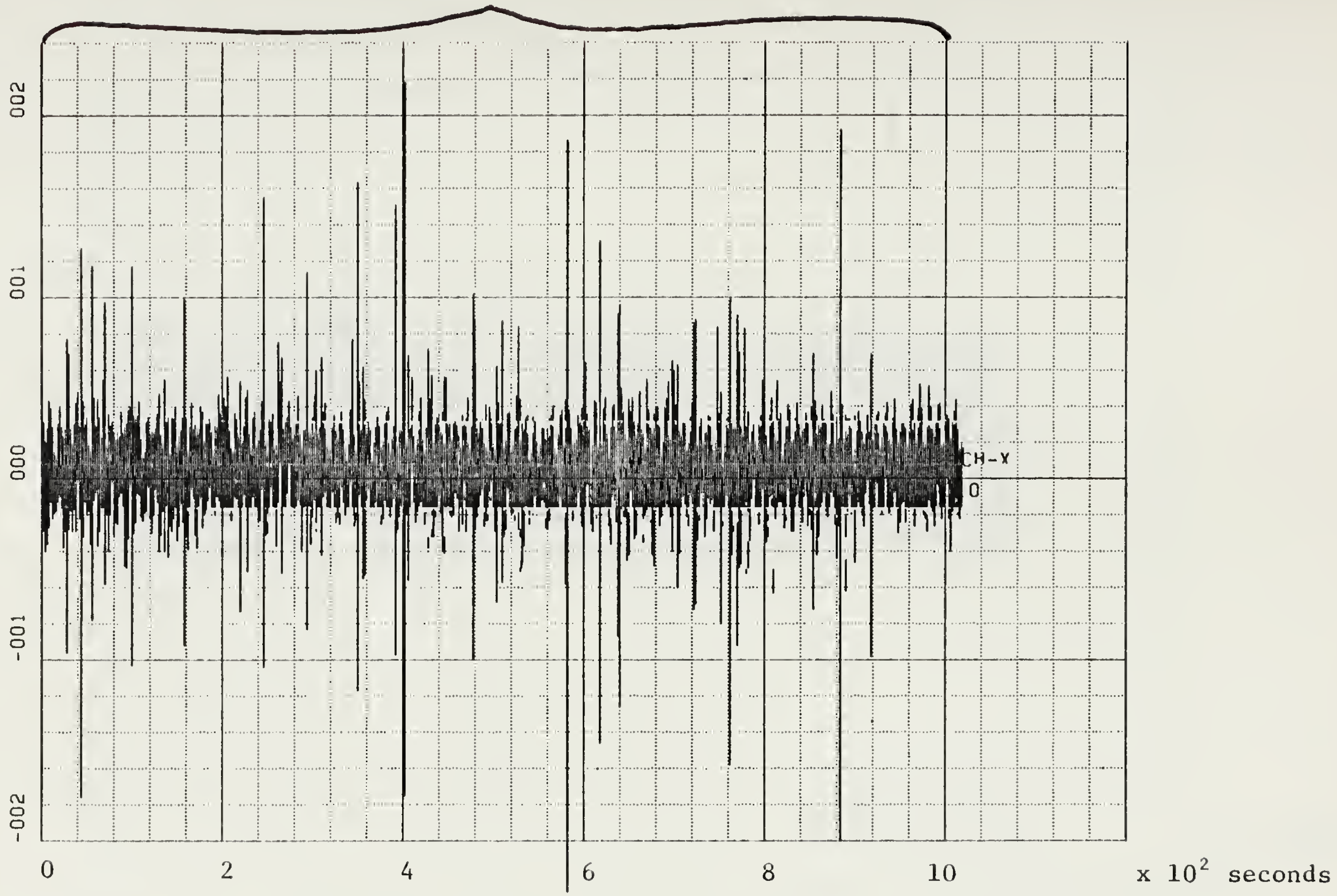

Figure 4.2. X-Coil Voltage, 26 April 83, 0931-0948 Local.
Amplitude (volts : 1 unit/in) vs. Time (seconds : 200 units/in)

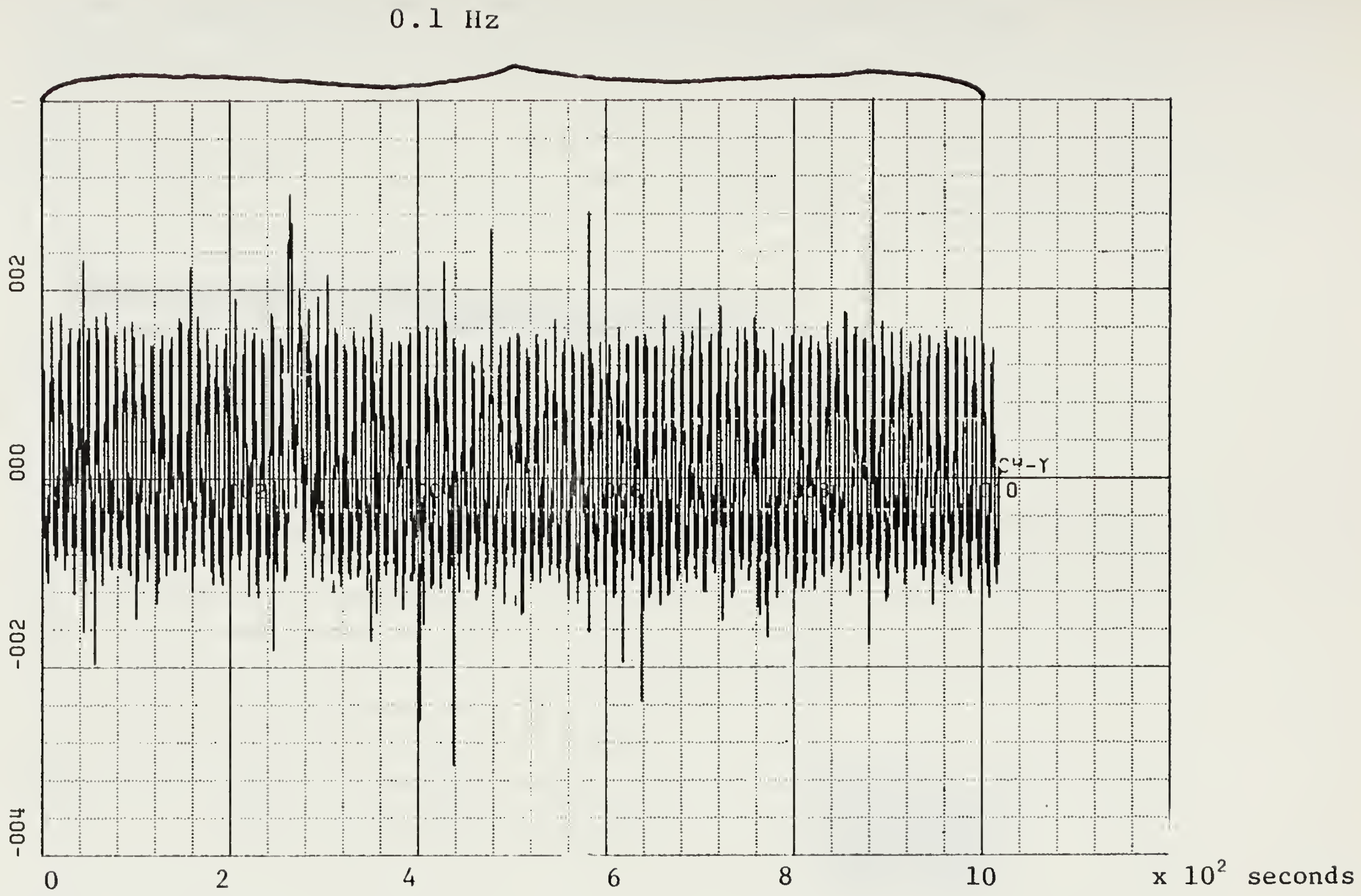

Figure 4.3. Filtered X-Coil Voltage, 26 April 83, 0931-0948 Local. Amplitude (volts : 0.2 units/in) vs. Time (seconds : 200 units/in)

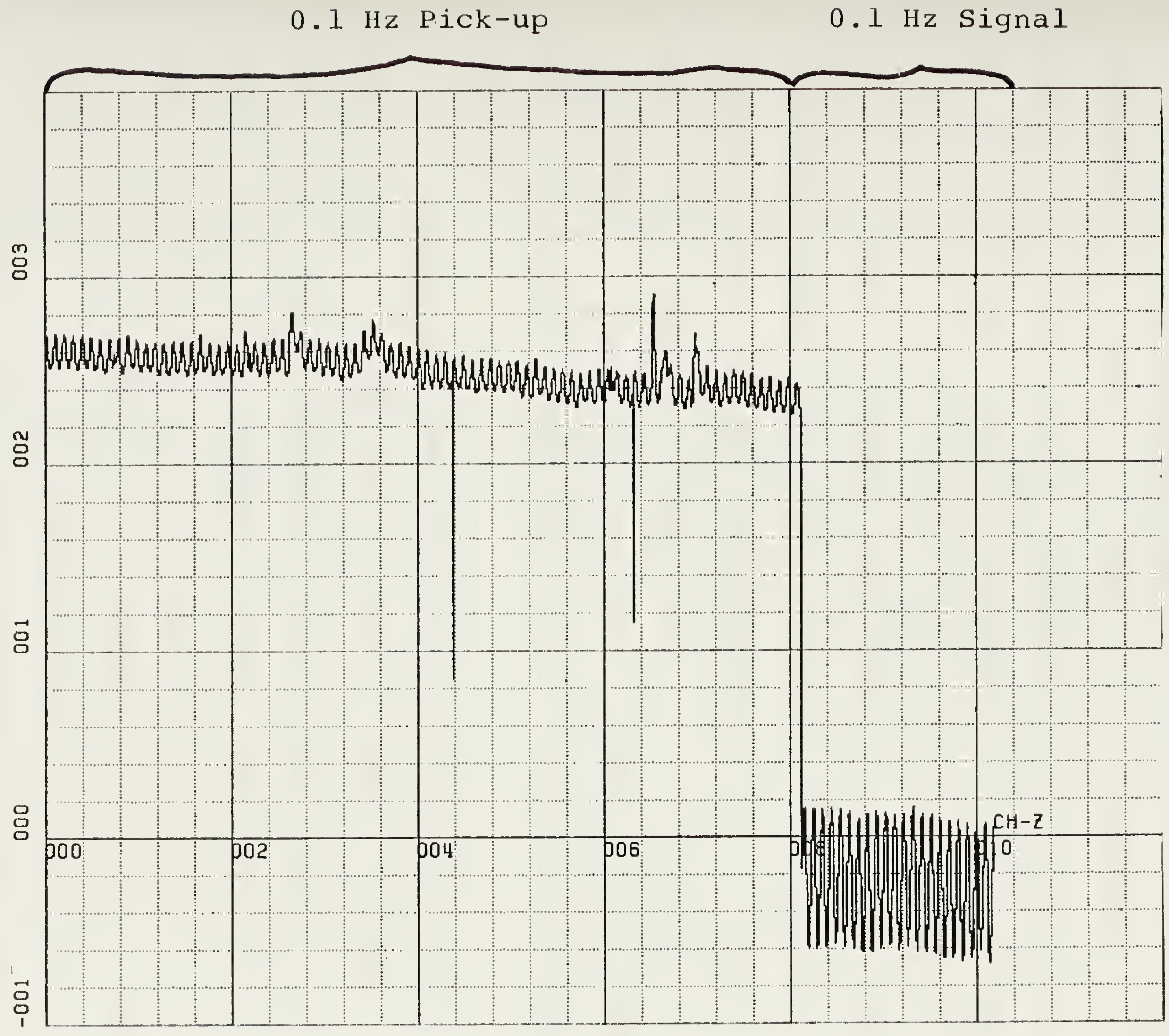

Figure 4.4. Fluxgate Voltage, 26 April 83, 0931-0948 Local.
Amplitude (volts : 1 unit/in) vs. Time (seconds : 200 units/in)

through the PCM encoder and decoder, the noise is probably in the coil amplifiers or the coils themselves. An experiment to investigate the true origin of the noise should be done.

2. Magnetic Field

Given the dipole equation [Ref. 6] and the experimental arrangement in Figure 4.1, the ratio of magnitude of the magnetic field seen by the fluxgate to that seen by the coil can be calculated. From the geometry in Figure 4.1 the field at the coil would be a factor of 8 less than that seen by the fluxgate. This is because the source is a dipole and the field of a dipole falls off as 1/R . Detailed consideration of the geometry gives a ratio of approximately 8.09. Table 4.3 contains the magnetic field measured at the fluxgate magnetometer. Using the ratio calculated from the geometry, the expected magnetic field amplitude at the coil is listed in Table 4.3.

A modified form of computer code LFVTC1 generated the magnetic field versus time plots for the test tapes. Table 4.3 shows the computer generated peak-to-peak magnetic field values read from the computer plots. From Table 4.3 it appears that the coil magnetic field amplitude is in error by a factor of approximately three (with exception to the low frequencies). One can conclude that a problem exists in the software.

Figures 4.8-4.9 show the magnetic field data for the second seventeen minutes of digital data tape GMTT1A. Figure 4.9 is the magnetic field measured by the fluxgate magnetometer

Table 4.3. Measured and Computer Generated Magnetic Field Magnitudes

FREQUENCY (HZ)	KNOWN FLUXGATE FIELD (nT)		EXPECTED COIL FIELD (nT)		EXPECTED RATIO FLUXGATE/COIL		COMPUTER COIL FIELD (nT)		ACTUAL RATIO FLUXGATE/COIL	
	LARGE AMPLITUDE OSCILLATION	SMALL AMPLITUDE OSCILLATION	LARGE AMPLITUDE OSCILLATION	SMALL AMPLITUDE OSCILLATION	LARGE AMPLITUDE OSCILLATION	SMALL AMPLITUDE OSCILLATION	LARGE AMPLITUDE OSCILLATION	SMALL AMPLITUDE OSCILLATION	LARGE AMPLITUDE OSCILLATION	SMALL AMPLITUDE OSCILLATION
0.1	24.50	7.80	3.04	0.96	8.06	8.12	1.08	0.30	22.69	26.00
0.09	24.50	8.00	3.03	0.99	8.09	8.08	1.00	0.35	24.50	22.86
0.08	24.50	7.80	3.04	0.96	8.06	8.12	0.98	0.30	25.00	26.00
0.07	24.40	7.00	3.02	0.87	8.08	8.05	0.98	0.32	24.89	21.88
0.06	24.60	7.70	3.05	0.94	8.07	8.19	0.90	0.30	27.33	25.67
0.05	24.50	7.90	3.03	0.98	8.09	8.06	0.76	0.35	32.23	22.57
0.04	24.10	7.80	3.01	0.96	8.01	8.12	0.28	0.24	86.07	32.5
0.03	25.00	8.20	3.09	1.01	8.09	8.12	0.32	0.14	78.13	58.57
0.02	25.00	7.60	3.09	0.92	8.09	8.26	0.64	0.24	39.06	31.67
0.01	25.00	7.80	3.09	0.96	8.09	8.12	0.40	0.14	62.50	55.71

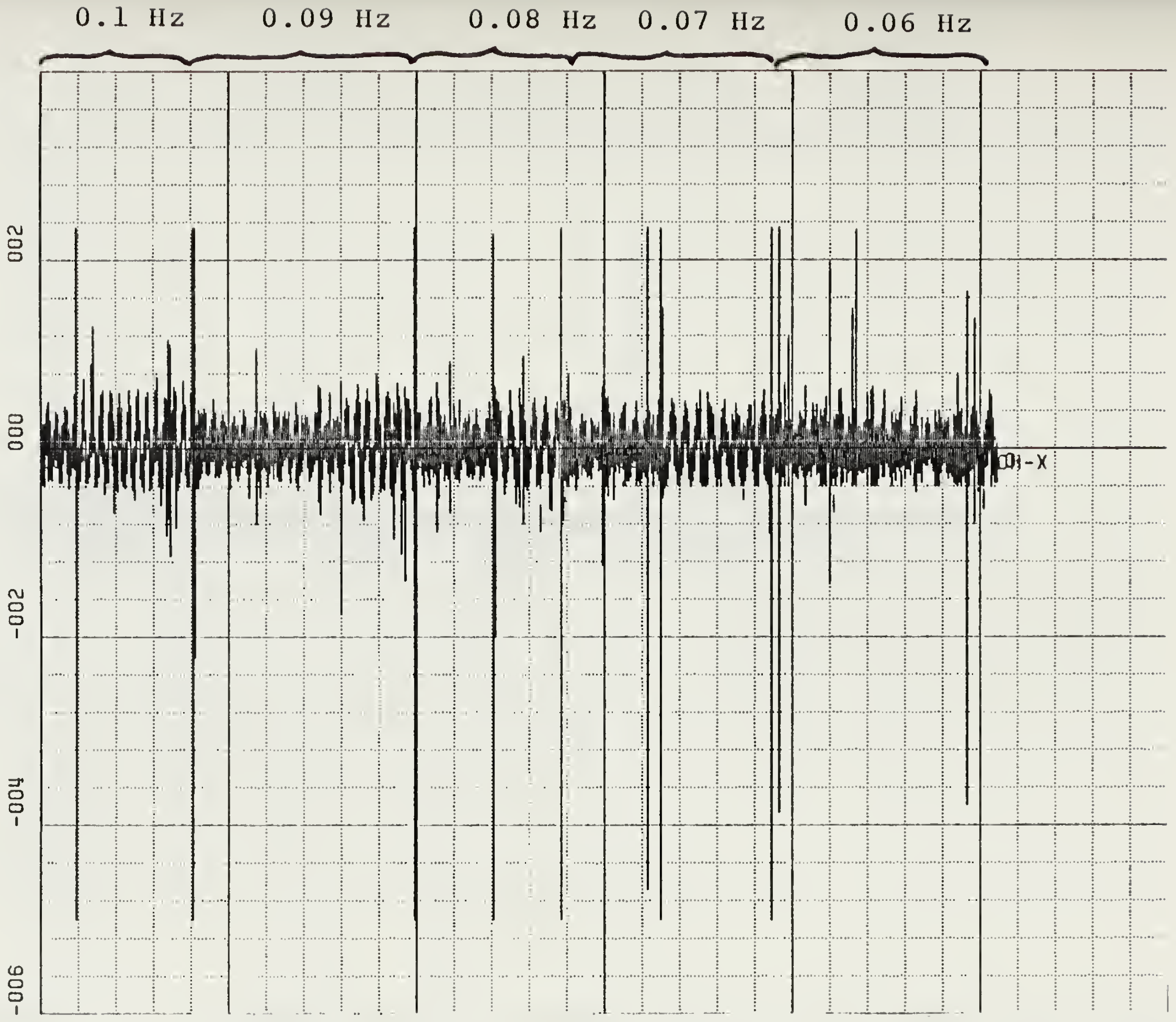

Figure 4.5. X-Coil Voltage, 26 April 83, 0948-1005 Local.
Amplitude (volts : 2 units/in) vs. Time (seconds : 200 units/in)

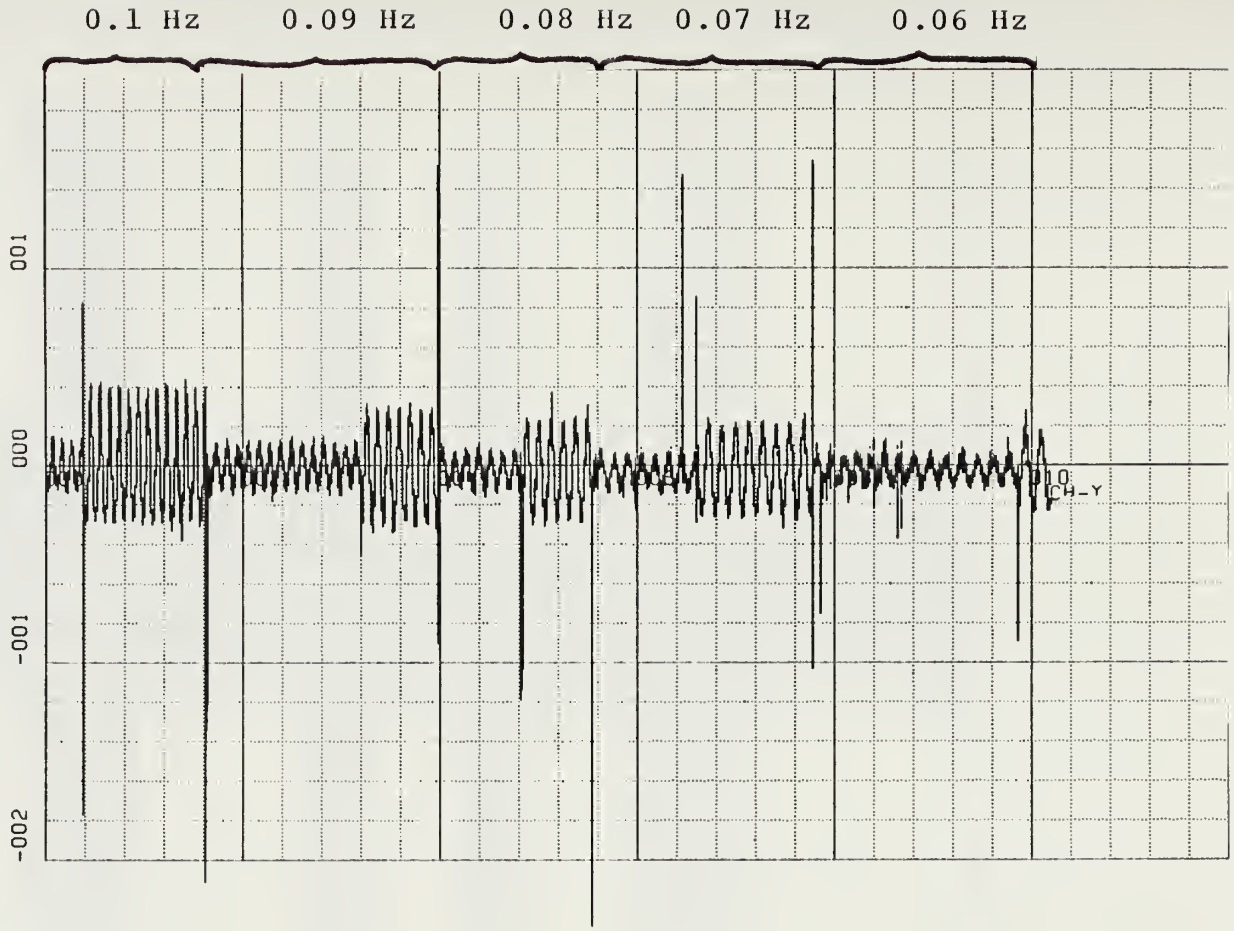

Figure 4.6. Filtered X-Coil Voltage, 26 April 83, 0948-1005 Local. Amplitude (volts : 1 unit/in) vs. Time (seconds : 200 units/in)

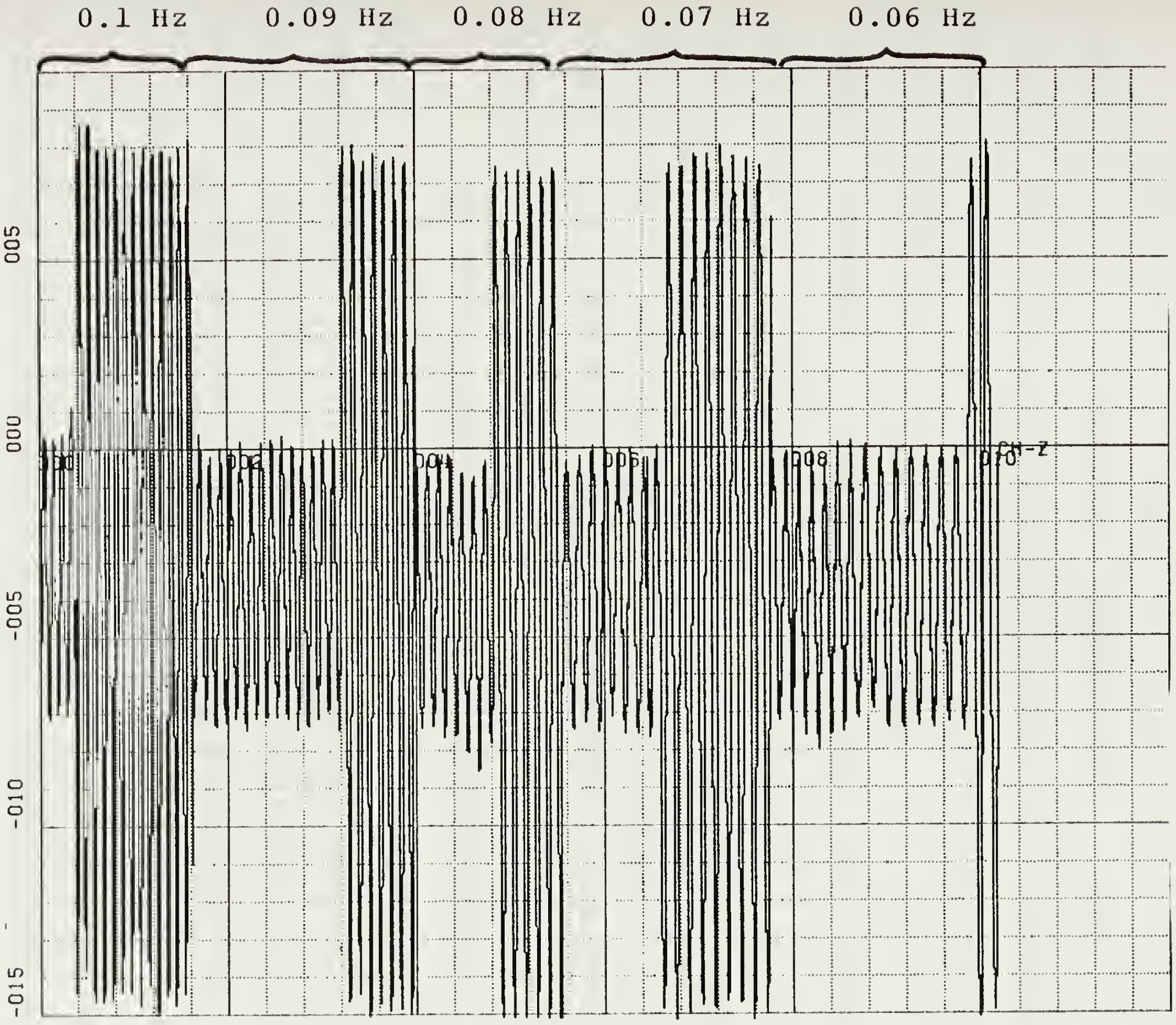

Figure 4.7. Fluxgate Voltage, 26 April 83, 0948-1005 Local. Amplitude (volts : 0.5 units/in) vs. Time (seconds : 200 units/in)

and Figure 4.8 is the magnetic field seen by the coil. For the coil we see discontinuities every 256 seconds corresponding to the block size of data. This indicates that the problems in the data block end points, as mentioned in Section III, do exist. It is not clear how to deal with this.

The first 300 seconds of Figures 4.8-4.9 is expanded in Figures 4.11-4.12. With the expanded data a phase difference between coil and fluxgate can be determined. By checking the phase differece, we can determine whether the phase independent transfer function is introducing error. For the 0.1 hertz field plotted in Figures 4.10-4.11 the coil lags the fluxgate by approximately 72 degrees. In Figures 4.12-4.13 we see that at 0.01 hertz the coil sensitivity has fallen and a reliable phase difference between the fluxgate and coil cannot be made. Figure 4.14 shows the relationship between phase angle and frequency.

The above experiment shows the advantages of having a real time "ground truth" record. With this, one can avoid "working in the blind". Computer products will have a check. Thus, a multi-channel chart recorder should be purchased to graph in real time the x, y, and z inputs to the PCM board. In addition, electronic circuitry should be developed and incorporated so that the chart records represent at least a low pass filtering of the coil voltages. Ideally, conversion of voltage to magnetic field could occur in real time at this point given the appropriate electronics.

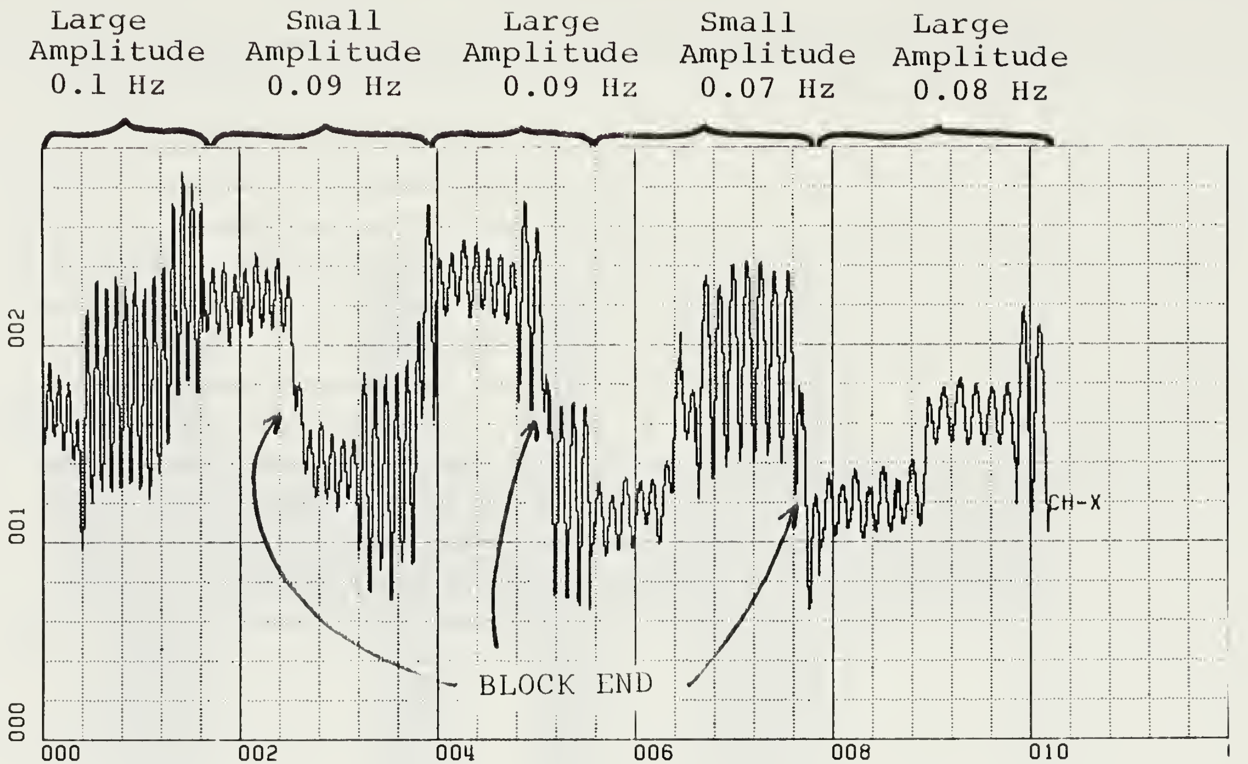

Figure 4.8. X-Coil Magnetic Field, 26 April 83, 0948-1005 Local. Amplitude (nanoteslas : 1 unit/in) vs. Time (seconds : 200 units/in)

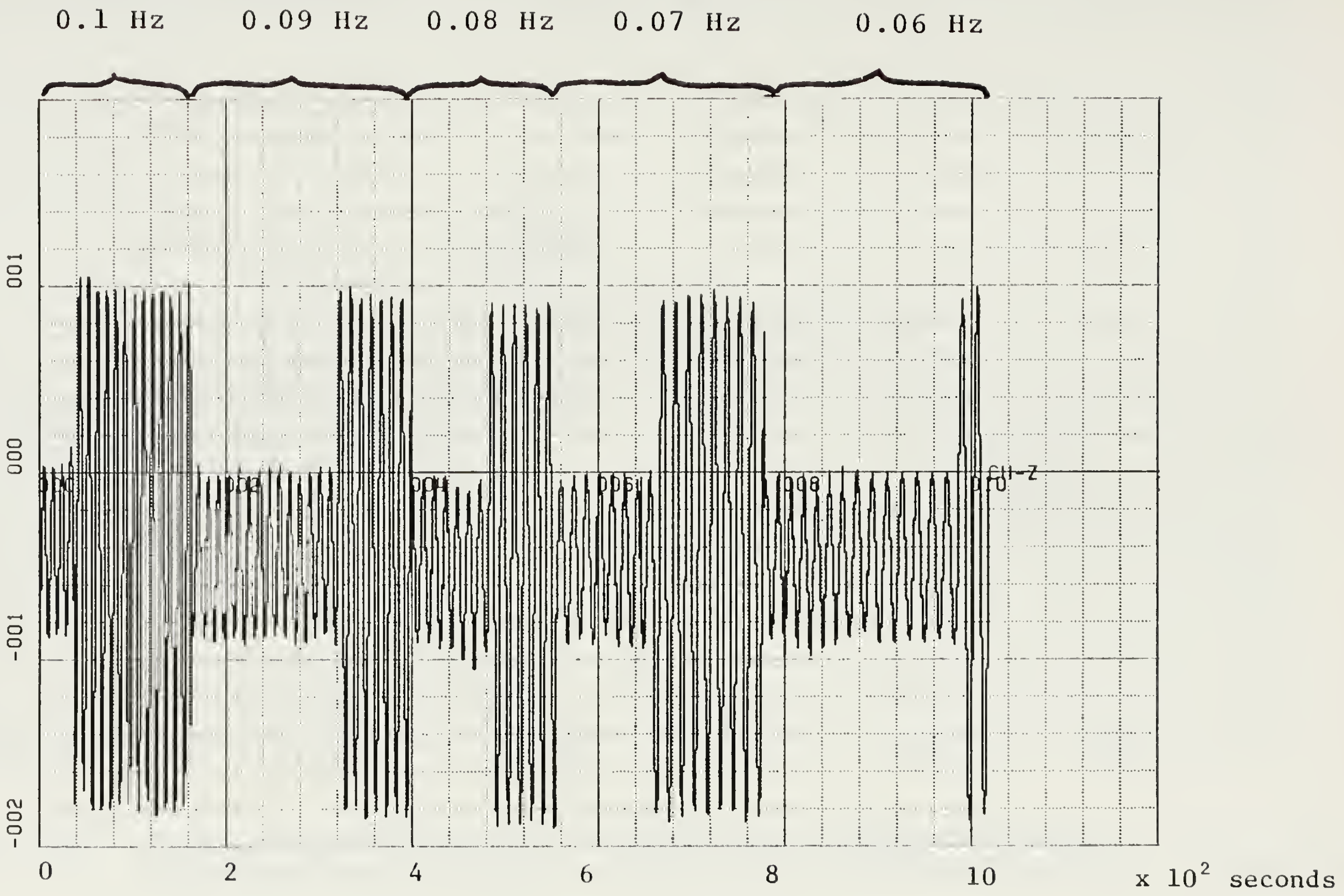

Figure 4.9. Fluxgate Magnetic Field, 26 April 83, 0948-1005 Local. Amplitude (nanoteslas : 10 units/in) vs. Time (seconds : 200 units/in)

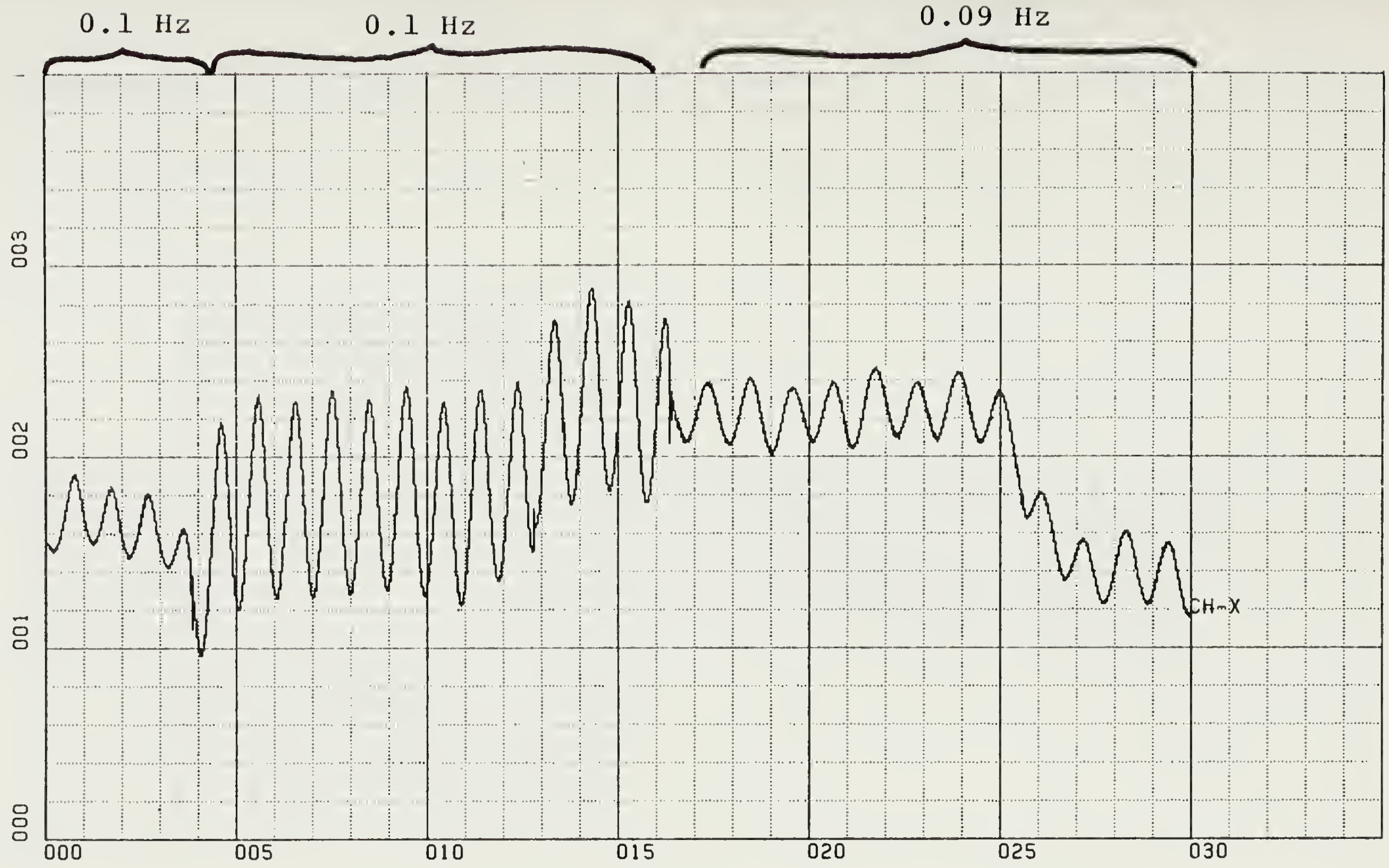

Figure 4.10. X-Coil Magnetic Field, 26 April 83, 0948-0953 Local.
Amplitude (nanoteslas : 1 units/in) vs. Time (seconds : 50 units/in)

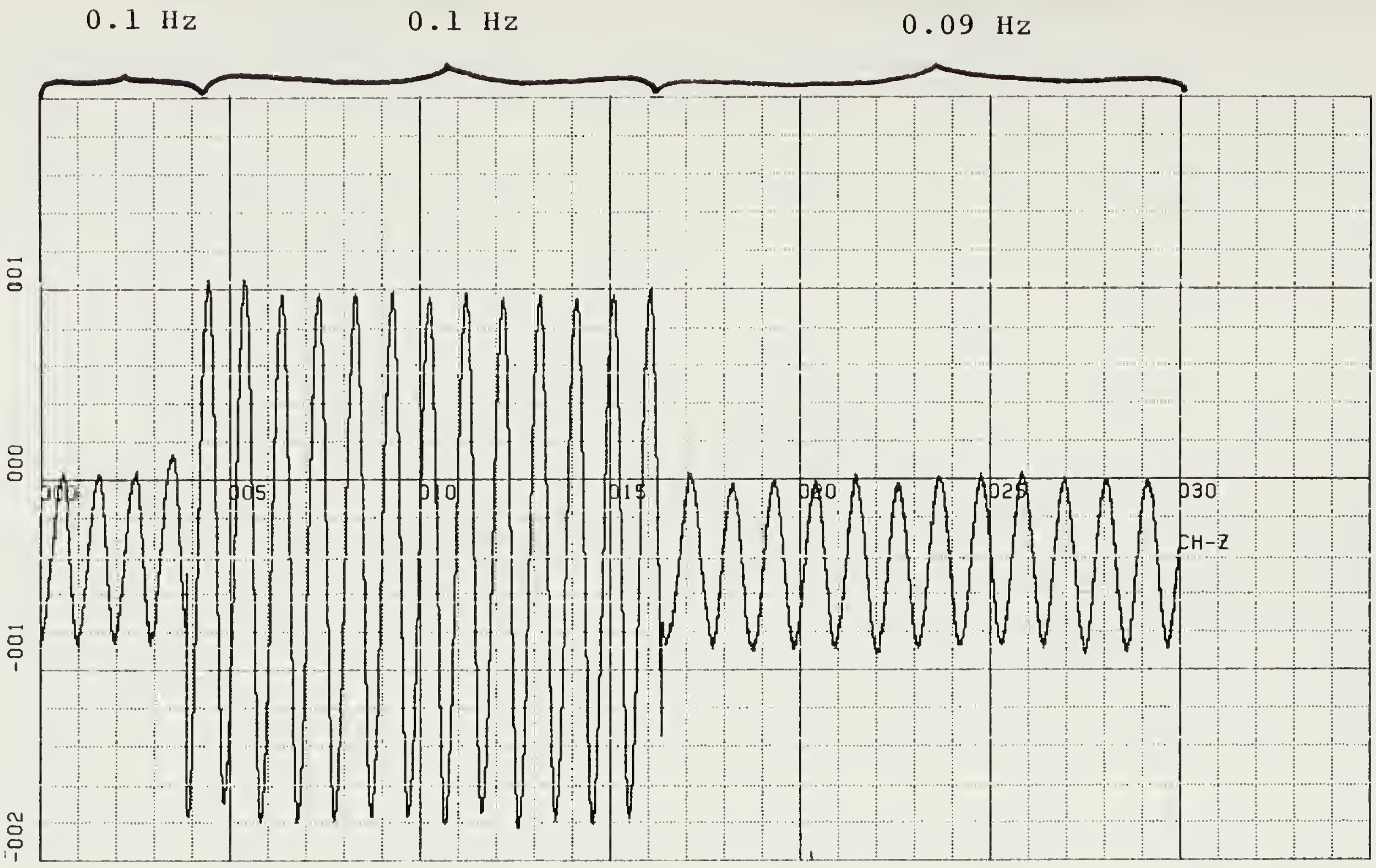

Figure 4.11. Fluxgate Magnetic Field, 26 April 83, 0948-0953 Local. Amplitude (nanoteslas : 10 units/in) vs. Time (seconds : 50 units/in)

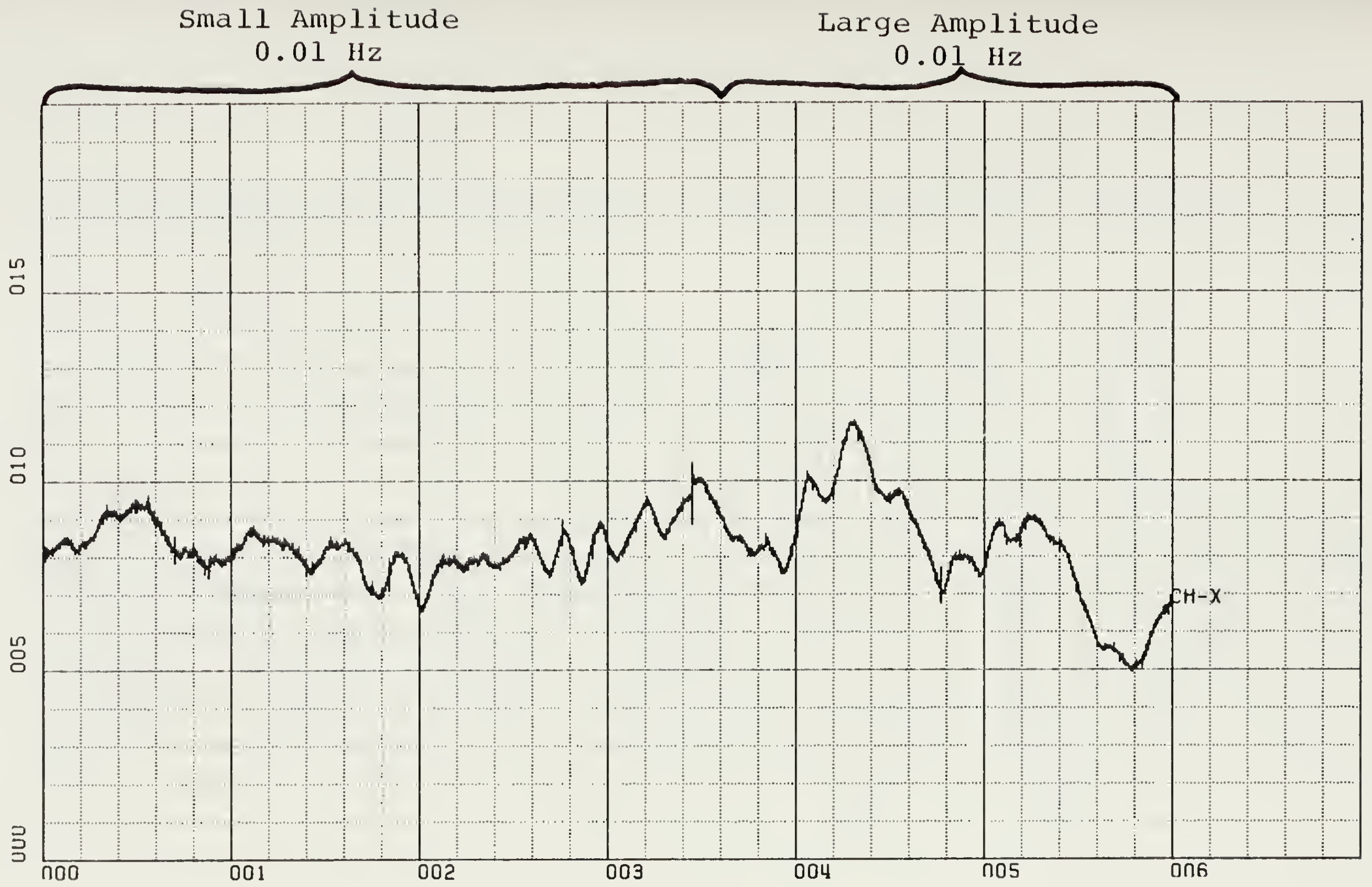

Figure 4.12. X-Coil Magnetic Field, 26 April 83, 1023-1033 Local.
Amplitude (nanoteslas : 0.5 units/in) vs. Time (seconds : 100 units/in)

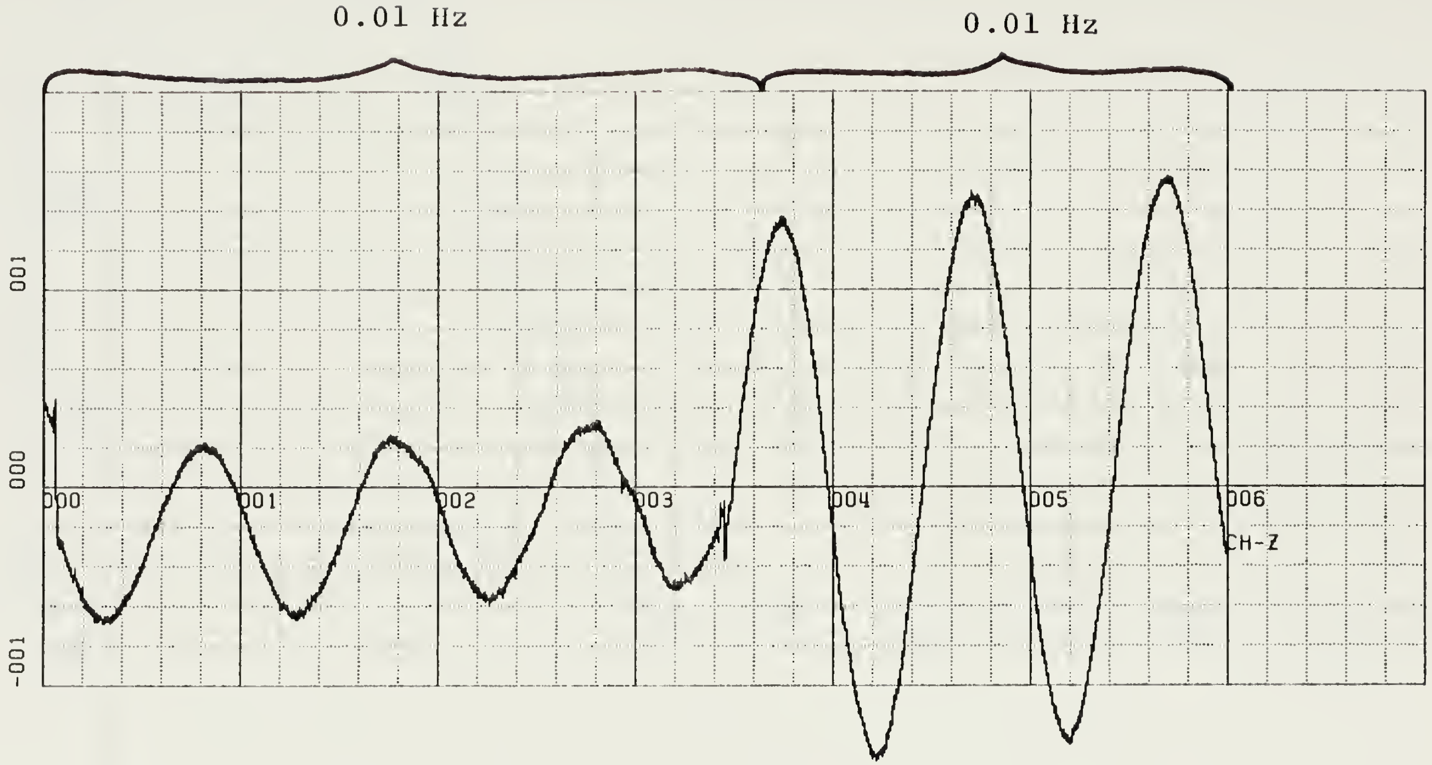

Figure 4.13. Fluxgate Magnetic Field, 26 April 83, 1023-1033 Local. Amplitude (nanoteslas : 10 units/in) vs. Time (seconds : 100 units/in)

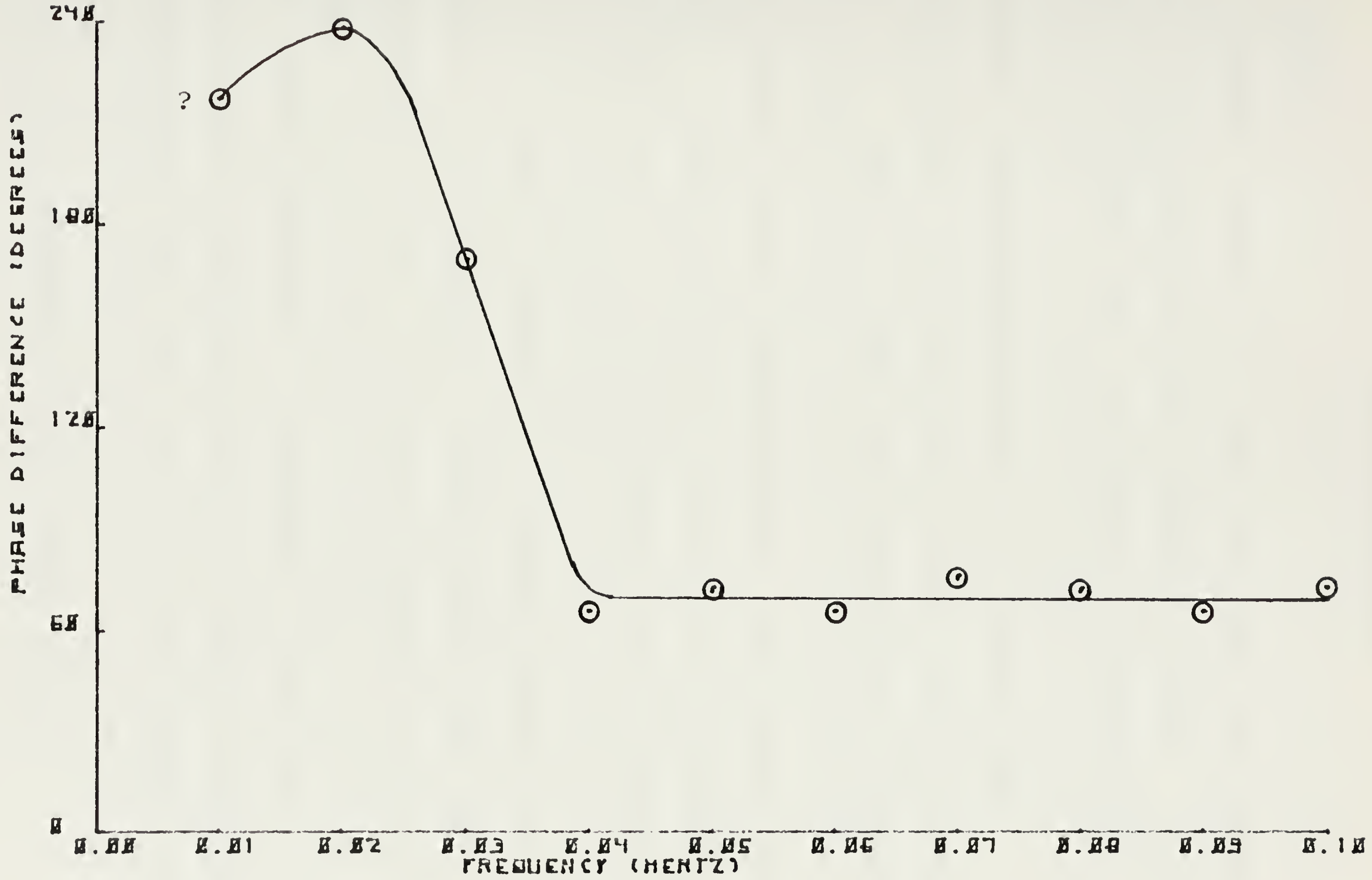

Figure 4.14. Phase Lag of Coil with Respect to Fluxgate

V. MICROPULSATIONS

A. THEORY

Currently there is no theory that completely models the observed micropulsations and geomagnetic noise. It is generally accepted that the generating mechanism for micropulsations is an interaction between the solar wind and the earth's magnetosphere [Ref. 5]. The observed micropulsations are classified by their period and regularity [Ref. 5]. Table 5.1 shows the micropulsation classification. The smoothing algorithm applied to the magnetic field data is designed to highlight micropulsations with periods between 10-45 seconds. Specifically we are interested in micropulsations classified as Pc 3. Pc 3 micropulsations are generally regular and have a more or less distinct period. Thus in the PSD plots we will be able to identify the micropulsation by an apparent anomaly at its frequency. Micropulsations have amplitudes of approximately 0.5 nT. This small amplitude is very small compared to a main magnetic field value of 50,000 nT, hence the term "micro" pulsations. Geomagnetic fluctuations are a combination of micropulsations and a general background noise. Micropulsation events grow out of the ever present background. The time series magnetic field plots will provide a means of obtaining the frequency of the micropulsation.

Table 5.1. Micropulsation Classification

Notation	Period (seconds)
Pc1	0.2-5
Pc2	5-10
Pc3	10-45
Pc4	45-150
Pc5	150-600

B. MICROPULSATION DATA ANALYSIS

The first 1200 seconds of data after a 60 second tape advance on digital data tape GMDT 11, 17 August 82, 1301-1408 Local, may contain a micropulsation event. Figures 3.10-3.12 show the first 34 minutes of GMDT 11 after a 60 second advance. To determine whether the regular pulsations we see in the first third of Figures 3.10-3.12 (disregarding the suspicious "cusps") is a micropulsation, the scale must be expanded. Figures 5.1-5.3 show the regular pulsations on an expanded scale. From Figures 5.1-5.3 the period of the oscillation is calculated to be 17.2 seconds. Thus this section of data contains a type Pc 3 micropulsation.

Executing the computer code LANDXYZ [Ref. 1] on this section of data, we generate the PSD, coherence, degree of polarization, and ellipticity. Table 5.2 contains the amplitude, frequency, coherence, etc. for the micropulsation.

At the frequency of the micropulsation one would expect a good coherence, degree of polarization and ellipticity since the coil system is oriented arbitrarily with each coil sensing the micropulsation. The observed micropulsation exhibits a high coherence as shown in Table 5.2. The observed micropulsation has a high degree of polarization. Micropulsations are generally considered to be left-hand elliptically polarized [Ref. 5]. The observed micropulsation is elliptically polarized.

If the errors in phase and amplitude that were shown to exist in Section IV are constant, then that should not be a

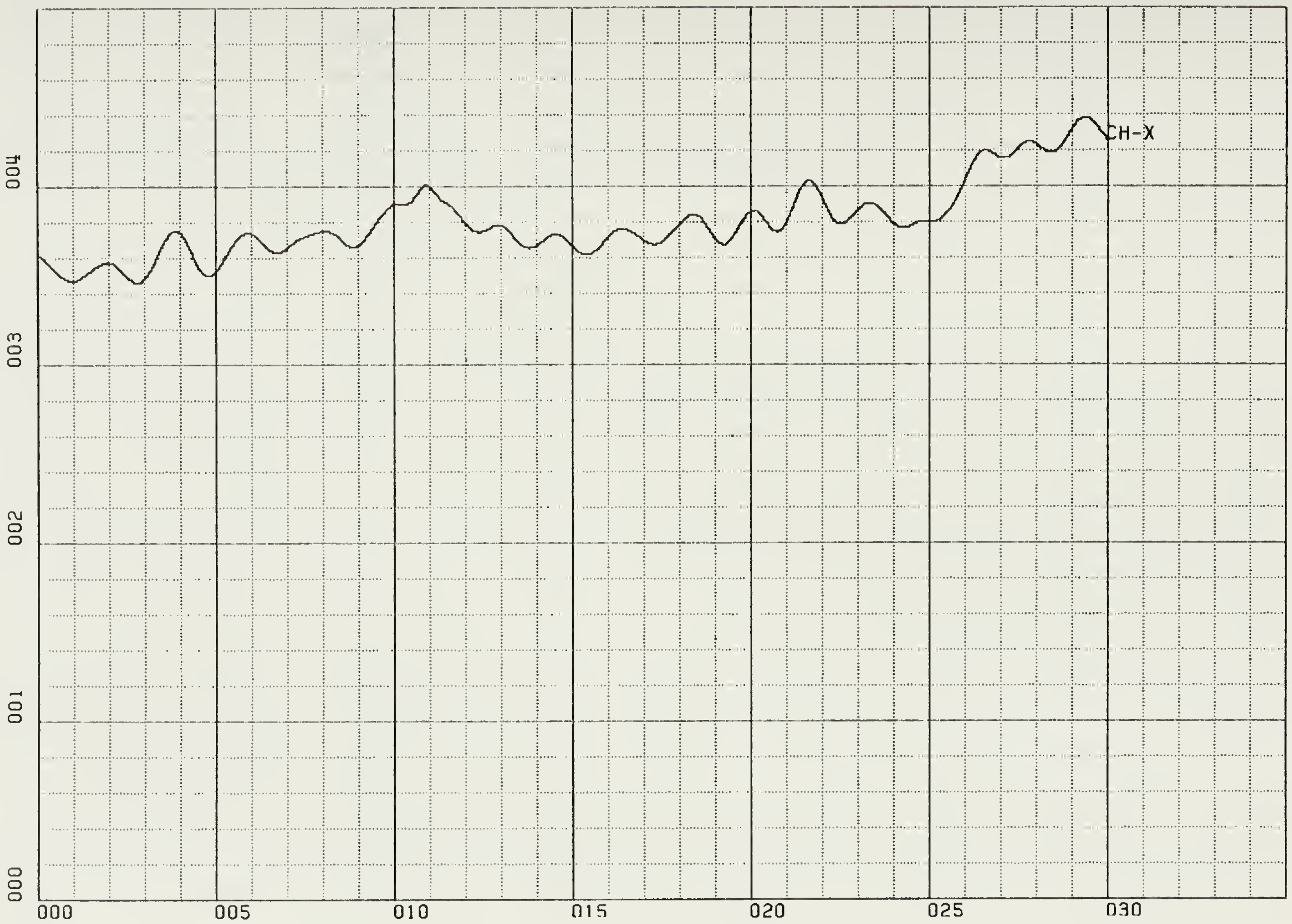

Figure 5.1. X-Coil Magnetic Field, 17 August 82, 1305-1310 Local.
Amplitude (nanoteslas : 1 unit/in) vs. Time (seconds : 50 units/in)

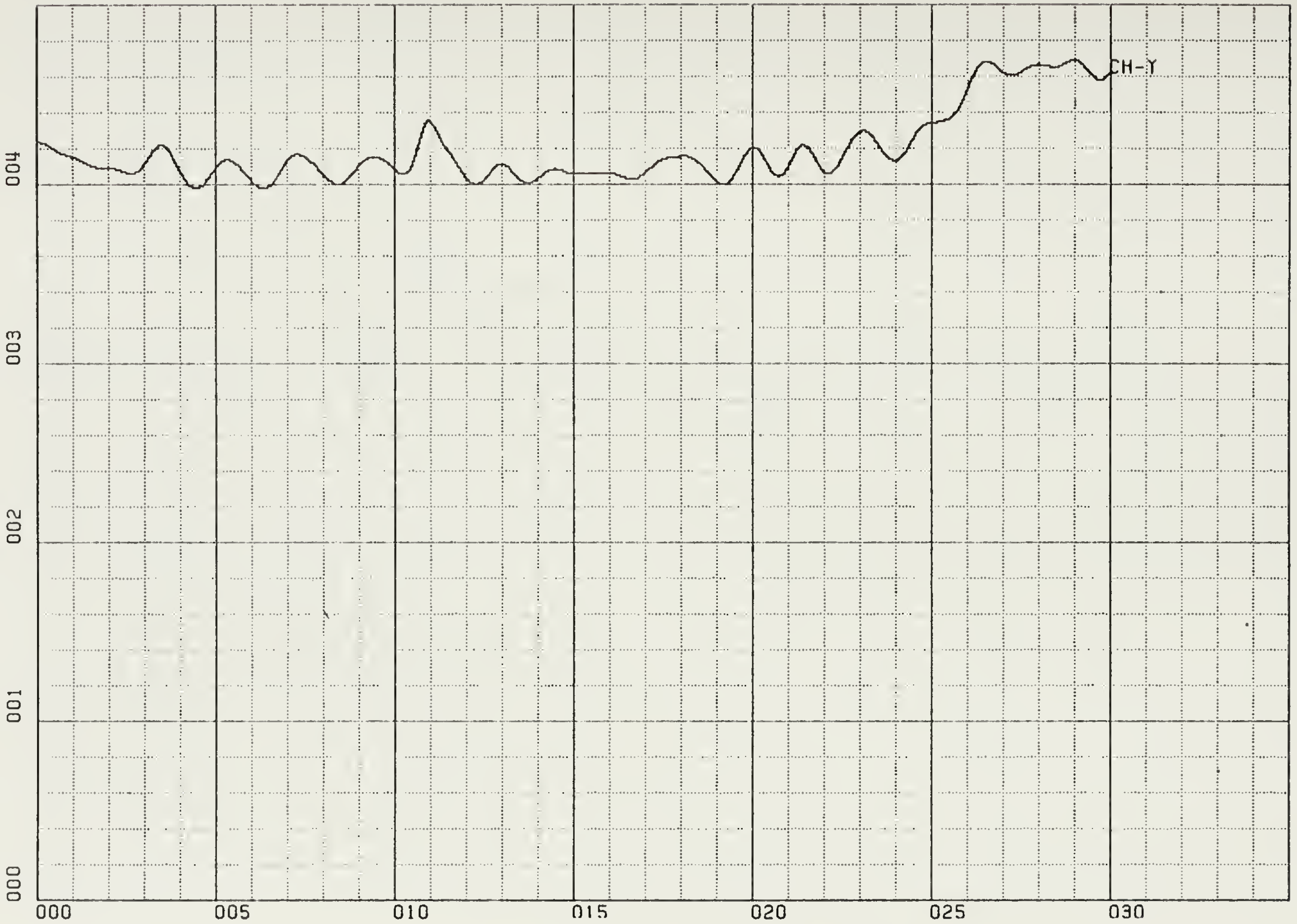

Figure 5.2. Y Coil Magnetic Field, 17 August 82, 1305-1310 Local.
Amplitude (nanoteslas : 1 unit/in) vs. Time (seconds : 50 units/in)

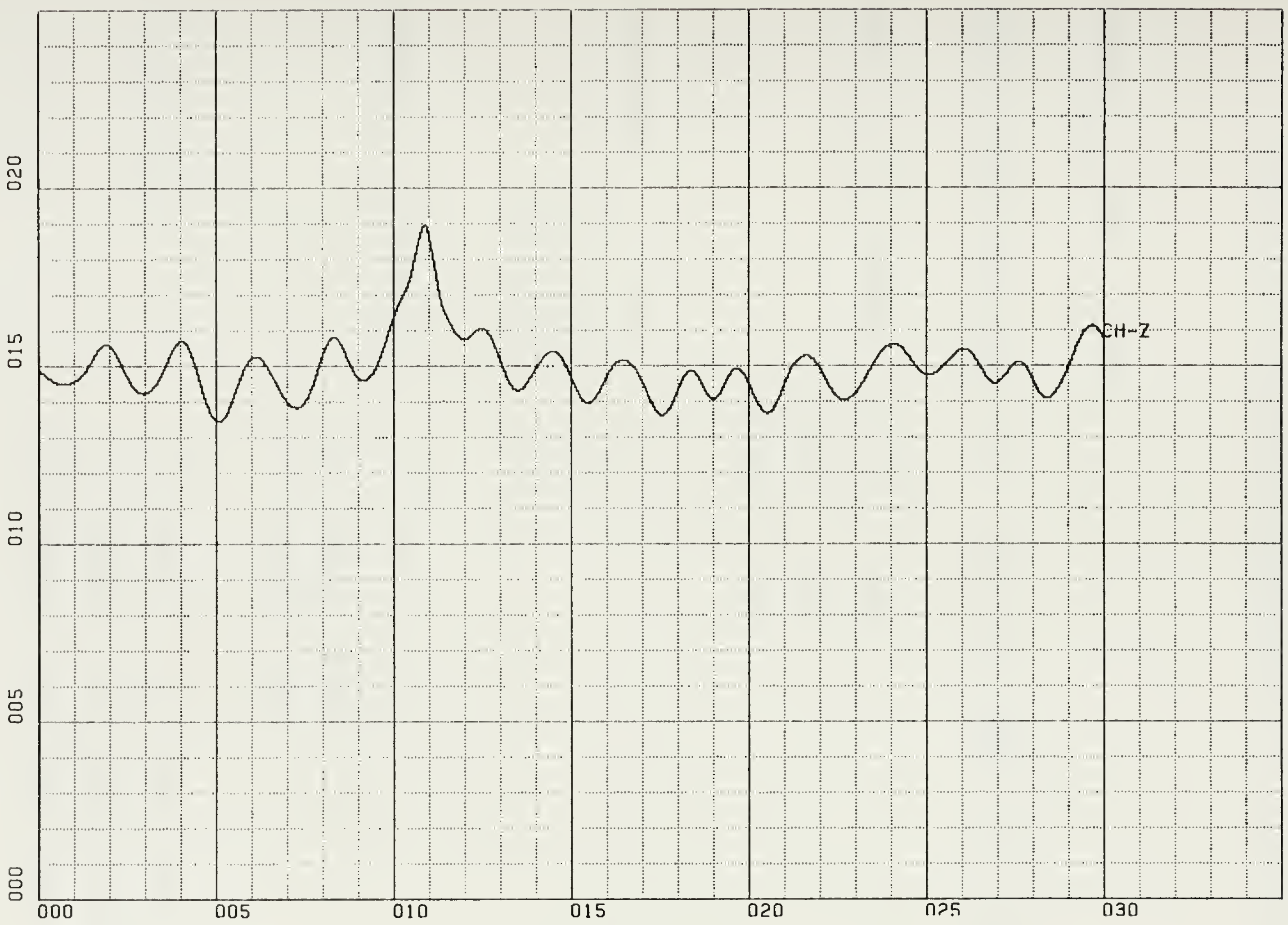

Figure 5.3. Z Coil Magnetic Field, 17 August 82, 1305-1310 Local.
Amplitude (nanoteslas : 0.5 units/in) vs. Time (seconds : 50 units/in)

Table 5.2. Observed Micropulsation Properties

Frequency (Hz): 0.058

Peak-to-Peak Amplitude (nT): Amplitude $=\sqrt{X^2 + Y^2 + Z^2} = 0.37$

PSD (dB) (Ref $1\mathrm{nT}^2/\mathrm{Hz}$): X-Coil: -3dB
Y-Coil: -4dB
Z-Coil: 1.5dB

Coherence: X-Y Coils: 0.99
Y-Z Coils: 0.99
Z-X Coils: 0.99

Degree of Polarization: X-Y Plane: 0.99
Y-Z Plane: 0.99
Z-X Plane: 0.99

Ellipticity: X-Y Plane: 0.45 (left hand)
Y-Z Plane: 0.10 (right hand)
Z-X Plane: 0.30 (left hand)

serious problem since we are dealing with a single frequency. Thus, the observed micropulsation exhibited definite structure decidedly different than the background.

VI. CONCLUSIONS

A type PC-3 micropulsation event of peak-to-peak amplitude (0.37 nT) and period (17.2 seconds) was identified in a section of data. At the frequency of the micropulsation, the coherence between the three orthogonal coil sensors was about 0.99 for the xy-pair, 0.99 for the xz-pair, and 0.99 for the yz-pair. The degree of polarization was 0.99. The ellipticity was about 0.30.

The origin of the regular "hump"-like structure in the PSD's of previous coil data was found to be artificial and not representative in any way of natural phenomena in the geomagnetic field. Previous conclusions based on a frequency domain analysis of coil data characterized by a regular "hump' structure (strong or weak) in the PSD plots are known to be unsubstantiated.

Compared to a PSD frequency domain analysis of the data set, an analysis of geomagnetic field fluctuations in the time domain easily identifies data sets containing a micropulsation event. A double running average routine developed and applied to the time series data sets was found to be helpful in highlighting the micropulsation.

Detailed conclusions about the geomagnetic field from the coil measurements require a balance of analysis in the frequency and time domain.

An accurate reproduction of a time series plot for the geomagnetic field oscillations will require modification to the existing software.

Comparisons in the time or frequency domain between any pair of coils in the orthogonal system might be misleading as a result of cross talk between electrical inputs. The suspicion of cross talk is based on the observed pick-up on an unloaded input of the contents of an adjacent loaded and active input.

Further micropulsation studies should continue. This initial investigation of the coherence, polarization, and ellipticity features of micropulsation events shows promise that with more data, one might suggest novel physical mechanisms and models for the origin of micropulsations.

APPENDIX A

VOLTR COMPUTER PROGRAM

Appendix A contains the VOLTR computer program that provides unsmoothed time series voltage plots. VOLTR uses the subroutine RD to strip voltage data off digital tapes. The integer voltage data is normalized to ± 5V and plotted using the DRAWP subroutine.

```
//VGLT$IL JOB (1C29,0129),'STEVENS   SMC 2670',CLASS=G                 VTH00010
//*MAIN ORG=NPGVM1.1029P,LINES=(65)                                       VTH00020
//*FCRMAT PR,DDNAME=PLOT.SYSVECTR,DEST=LOCAL                              VTH00030
// EXEC FRTXCLGP,PARM.LKED='LIST,MAP,XREF',REGION.GO=2048K                VTH00040
//FORT.SYSIN DD *                                                         VTH00050
      INTEGER*2 IN(16)                                                    VTH00060
C       ARRAY 'IN' IS USED IN READING DATA FROM TAPE                      VTH00070
      REAL*4 XX(8192),YY(8192),ZZ(8192)                                   VTH00080
C       THE ABOVE REAL*4 ARRAYS ARE USED TO ORDER INPUT DATA AND          VTH00090
C       INITIALLY REPRESENT VOLTAGE - TIME SERIES INFORMATION.            VTH00100
      DIMENSION ZZX1(65536),ZZY1(65536),ZZV1(65536)                       VTH00110
      DIMENSION TIME2(65536)                                              VTH00120
      INTEGER K,I5                                                        VTH00130
      INTEGER*4 ITB(12)/12*0/                                             VTH00140
      REAL*4    RTB(28)/28*0.0/                                           VTH00150
      REAL ALAB(3)/'CH-X','CH-Y','CH-Z'/                                  VTH00160
      REAL*8 TITLE(12)                                                    VTH00170
      EQUIVALENCE(TITLE(1),RTB(5))                                        VTH00180
C       ARRAYS 'ITB','RTB','ALAB',AND 'TITLE' ARE USED IN GENERATING      VTH00190
C       THE VERTSATEC PLCTTER CUTPUT.                                     VTH00200
      DATA XX,YY/16384*0./                                                VTH00210
      DATA ZZ/8192*0./                                                    VTH00220
      K=0                                                                 VTH00230
      I5=1                                                                VTH00240
      DC 31 IN1=1,65536                                                   VTH00250
      ZZX1(IN1)=0.0                                                       VTH00260
      ZZY1(IN1)=C.0                                                       VTH00270
      ZZV1(IN1)=C.0                                                       VTH00280
      TIME2(IN1)=0.0                                                      VTH00290
   31 CCNTINUE                                                            VTH00300
C        THE NEXT FIVE LINES SERVE AS A TIME DELAY IN STARTING THE        VTH00310
C        DATA ANALYSIS. ISEC IS THE NUMBER OF SECCNDS DELAYED.            VTH00320
      ISEC=2048                                                           VTH00330
      ITL=ISEC*32                                                         VTH00340
      DC 55 JJ=1,ITL                                                      VTH00350
      CALL RD(20,IN,200,IREC,IRR)                                         VTH00360
   55 CCNTINUE                                                            VTH00370
      IFRAME=8192                                                         VTH00380
      NR=8                                                                VTH00390
      FNR=FLOAT(NR)                                                       VTH00400
      DC 70 L1=1,NR                                                       VTH00410
C       THE DO LOCP ENDING WITH STATEMENT 70 ENABLES THE PROGRAM TO       VTH00420
C       PROCESS A LARGE AMOUNT OF DATA BY REPEATING THE PROCESS IN        VTH00430
C       BLOCKS.                                                           VTH00440
C       'NR' REPRESENTS THE NUMBER OF DATA SEQUENCES. CNE                 VTH00450
C       SEQUENCE CURRENTLY EQUALS 8192 DATA POINTS FCR EACH CHANNEL       VTH00460
C       CR 256 SECCNDS OF DATA.                                           VTH00470
C                                                                         VTH00480
```

```
C        THE DO LCCP ENDING WITH 60 READS THE DATA FROM THE PCM FRAME      VTH00490
C        STRIPS OUT THE SYNC CODE, AND SORTS OUT THE DATA BY COIL          VTH00500
C        CHANNEL.                                                           VTH00510
      DO 60 JJ=1,IFRAME                                                     VTH00520
      CALL RD(20,IN,1000,IREC,IRR)                                          VTH00530
      XX(JJ)=IN(2)                                                          VTH00540
      YY(JJ)=IN(3)                                                          VTH00550
      ZZ(JJ)=IN(4)                                                          VTH00560
   60 CCNTINUE                                                              VTH00570
      N=8192                                                                VTH00580
      FN=FLOAT(N)                                                           VTH00590
      DELTAT=1./32.                                                         VTH00600
      DO 20 J=1,N                                                           VTH00610
C     THE FOLLOWING CALCULATIONS NORMALIZE THE DATA TO +5V AND -5V.         VTH00620
      XX(J)=(XX(J)-1966.)*5./1966.                                          VTH00630
      YY(J)=(YY(J)-2085.)*5./2085.                                          VTH00640
      ZZ(J)=(ZZ(J)-2539.)*5./2539.                                          VTH00650
C        'XX' IS THE X-COIL DATA, 'YY' IS THE Y-COIL DATA,                  VTH00660
C        'ZZ' IS THE Z-COIL DATA                                            VTH00670
C        NORTH-SOUTH COMPONENT (XX) AND THE VERTICAL COMPONENT (ZZ)         VTH00680
   20 CONTINUE                                                              VTH00690
      DC 91 I3=1,8192                                                       VTH00700
      ZZX1(I5)=XX(I3)                                                       VTH00710
      ZZY1(I5)=YY(I3)                                                       VTH00720
      ZZV1(I5)=ZZ(I3)                                                       VTH00730
      TIME2(I5)=(DELTAT*FLOAT(I3))+(256.0*FLOAT(K))                         VTH00740
      I5=I5+1                                                               VTH00750
   91 CCNTINUE                                                              VTH00760
      K=K+1                                                                 VTH00770
   70 CCNTINUE                                                              VTH00780
C                                                                           VTH00790
C    VERSATEC PLOT OF V - TIME SERIES VOLTAGE                               VTH00800
C                                                                           VTH00810
      NPTS=2048./DELTAT +1.                                                 VTH00820
C        'NPTS' DETERMINES NUMBER OF POINTS NECESSARY IN ORDER FOR          VTH00830
C         THE 0 TO 2047  SECS RANGE TO BE PLOTTED.                          VTH00840
C        FOR THE FCLLOWING 'ITB' AND 'RTB' VALUES REVIEW THE WRITE-UP       VTH00850
C        FOR THE SUBROUTINE PROCEDURE 'DRAWP'.                              VTH00860
      ITB(3)=20                                                             VTH00870
      ITB(4)=8                                                              VTH00880
      ITB(7)=1                                                              VTH00890
      ITB(12)=0                                                             VTH00900
      RTB(1)=0.0                                                            VTH00910
      RTB(2)=0.0                                                            VTH00920
      RTB(3)=ALAB(1)                                                        VTH00930
      READ(5,3000)TITLE                                                     VTH00940
      CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)                                   VTH00950
      RTB(3)=ALAB(2)                                                        VTH00960
```

```
      READ(5,3000)TITLE                                                 VTH00970
      CALL  DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)                              VTH00980
      RTB(3)=ALAB(3)                                                    VTH00990
      READ(5,3000)TITLE                                                 VTH01000
      CALL  DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)                              VTH01010
      ITB(3)=7                                                          VTH01020
      ITB(4)=5                                                          VTH01030
      ITB(12)=0                                                         VTH01040
      RTB(3)=ALAB(1)                                                    VTH01050
      READ(5,3000)TITLE                                                 VTH01060
      CALL  DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)                              VTH01070
      RTB(3)=ALAB(2)                                                    VTH01080
      READ(5,3000)TITLE                                                 VTH01090
      CALL  DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)                              VTH01100
      RTB(3)=ALAB(3)                                                    VTH01110
      READ(5,3000)TITLE                                                 VTH01120
      CALL  DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)                              VTH01130
 3000 FORMAT(6A8)                                                       VTH01140
      STOP                                                              VTH01150
      END                                                               VTH01160
       SUBROUTINE RD(IUN,IO,IRS,IREC,IRQ)                               VTH01170
C                                                                       VTH01180
C         THIS PROCEDURE FURNISHED BY DR. TIM STANTON,                  VTH01190
C         DEPARTMENT OF OCEANOGRAPHY.                                   VTH01200
C                                                                       VTH01210
C              READ DATA FROM IUN, ALLIGN , CHECK & RETURN              VTH01220
C                                                                       VTH01230
C        IUN=TAPE NUMBER, EG 20                                         VTH01240
C        IO=INTEGER*2 ARRAY, 16 LONG,(VALUES 0-4095, SUBTRACT 2048)*5   VTH01250
C               /2028.  GIVES VOLTAGE                                   VTH01260
C        IRS= NUMBER OF RESINCS ALLOWED (ERRORS)                        VTH01270
C        IREC= COUNTER OF RECORDS (FRAMES OF DATA)                      VTH01280
C            BLOCK 512 BITS,   32 BITS = RECORD                         VTH01290
C            800 BPI TAPE UNLABLED                                      VTH01300
C        IRQ= NUMBER OF ACTUAL RESINCS (ERRORS)                         VTH01310
C                                                                       VTH01320
C                                                                       VTH01330
       INTEGER * 2 IO(16),IP(16)                                        VTH01340
       DATA  IRR  /0/                                                   VTH01350
       IF (IREC.EQ.0) IS=0                                              VTH01360
       IER=0                                                            VTH01370
  20   FORMAT (16A2)                                                    VTH01380
       IF (IS.NE.0) GO TO 50                                            VTH01390
       READ  (IUN,20,END=900) IP                                        VTH01400
       IREC=IREC+1                                                      VTH01410
  40   IS=IS+1                                                          VTH01420
       IF (IS.LT.17) GO TO 50                                           VTH01430
       READ  (IUN,20,END=900) IP                                        VTH01440
```

```
      IS=1                                                              VTH01450
      IREC=IREC+1                                                       VTH01460
   50 ICH=IMASK(IP(IS),3,0)+1                                           VTH01470
C      WRITE (6,55) ICH,IS,IUN,IREC                                     VTH01480
   55  FORMAT ('  RESYNCING ICH,IS,IUN,IREC ',4I8)                      VTH01490
C                                                                       VTH01500
      IF (ICH.NE.1) GO TO 40                                            VTH01510
      DO 100 I=1,16                                                     VTH01520
       IO(I)=ISHIFT(IP(IS),4)                                           VTH01530
      ICH=IMASK(IP(IS),3,0)+1                                           VTH01540
      IF (ICH.EQ.I) GO TO 80                                            VTH01550
      IER=IER+1                                                         VTH01560
      WRITE (6,70)  IUN,IREC ,I,ICH,IER                                 VTH01570
   70  FORMAT (' UNIT ',I3,' RECORD ',I6,'CHAN & DATA CH ',2I4,         VTH01580
     $ 'ERRORS ',I7)                                                    VTH01590
   80  IS=IS+1                                                          VTH01600
       IF (IS.LT.17) GO TO 100                                          VTH01610
       READ (IUN,20,END=900) IP                                         VTH01620
       IS=1                                                             VTH01630
       IREC=IREC+1                                                      VTH01640
  100  CONTINUE                                                         VTH01650
C                                                                       VTH01660
       IF (IER.EQ.0) GO TO 150                                          VTH01670
       IRR=IRR+1                                                        VTH01680
       IF (IRR.LT.IRS) GO TO 120                                        VTH01690
       WRITE (6,110)                                                    VTH01700
  110  FORMAT ('1 STOPPED IN SUB RD BECAUSE OF IRR.GT.',I6,' AT L110')  VTH01710
       IRQ=IRR                                                          VTH01720
       STOP                                                             VTH01730
  120  CONTINUE                                                         VTH01740
       WRITE (6,130) IREC,IRR                                           VTH01750
  130  FORMAT (' RESYNC AT FRAME ',I6,' WITH TOTAL ERRORS ',I7)         VTH01760
       IER=0                                                            VTH01770
       IRQ=IRR                                                          VTH01780
       GO TO 50                                                         VTH01790
  150  CONTINUE                                                         VTH01800
       RETURN                                                           VTH01810
  900  WRITE (6,910) IUN,IREC                                           VTH01820
  910  FORMAT ('1   END OF UNIT ',I3,' AT REC ',I7)                     VTH01830
       STOP                                                             VTH01840
       END                                                              VTH01850
                                                                        VTH01860
       FUNCTION ISHIFT (IN,NPLC)                                        VTH01870
C               RETURNS SHIFTED VALUE OF I*2 WORD IN                    VTH01880
C               -VE LEFT,+VE RIGHT SHIFT                                VTH01890
C                                                                       VTH01900
       INTEGER * 2 IN                                                   VTH01910
       IP=IN                                                            VTH01920
```

```
      IF (IP.LT.0) IP=IP+65536
      IF (NPLC.LT.0) GO TO 30
      ISHIFT=IP/(2**IABS(NPLC))
      RETURN
 30   ISHIFT=IP*(2**IABS(NPLC))
      IF (ISHIFT.GT.65535) ISHIFT=MOD(ISHIFT,65536)
      RETURN
      END
      FUNCTION IMASK (IN,IBL,IBR)
C               MASK I*2 WORD IN OUTSIDE BITS IBL & IBR
C
      INTEGER * 2 IN,IO
      IO=IN
      IF (IBR.EQ.0) GO TO 50
      IT=ISHIFT(IN,IBR)
      IO=IT
 50   IP=ISHIFT(IO,IBL-15-IBR)
      IO=IP
      IMASK=ISHIFT(IO,15-IBL)
      RETURN
      END
/*
//GO.SYSIN DD *
LA MESA VILLAGE, 17 AUG 82, 1324-1358 LOCAL
X COIL AMP IN VOLTS
LA MESA VILLAGE, 17 AUG 82, 2240-2314 LOCAL
Y COIL AMP IN VOLTS
LA MESA VILLAGE, 17 AUG 82, 1324-1358 LOCAL
Z COIL AMP IN VOLTS
LA MESA VILLAGE, 17 AUG 82, 1324-1358 LOCAL
X COIL AMP IN VOLTS
LA MESA VILLAGE, 17 AUG 82, 1324-1358 LOCAL
Y COIL AMP IN VOLTS
LA MESA VILLAGE, 17 AUG 82, 1324-1358 LOCAL
Z COIL AMP IN VOLTS
/*
//GO.FT20F001 DD UNIT=3400-4,VOL=SER=GMDT11,DISP=(OLD,KEEP),
//             LABEL=(1,NL,,IN),
//             DCB=(RECFM=FB,LRECL=32,BLKSIZE=512,DEN=2)
//GO.SYSDUMP DD SYSOUT=A
/*
//
```

APPENDIX B

VOLTS COMPUTER PROGRAM

Appendix B contains the VOLTS computer program that provides smoothed time series voltage plots. VOLTS uses the subroutine RD to strip voltage data off digital tapes. The integer voltage data is normalized to ± 5V. A double 144 point running average is applied to the data. The DRAWP subroutine plots the data.

```
//VLTS$IL JOB (1029,0129),'STEVENS    SMC 2670',CLASS=G                 VTH00010
//*MAIN ORG=NPGVM1.1029P,LINES=(65)                                     VTH00020
//*FORMAT PR,DDNAME=PLOT.SYSVECTR,DEST=LOCAL                            VTH00030
// EXEC FRTXCLGP,PARM.LKED='LIST,MAP,XREF',REGION.GO=2048K              VTH00040
//FORT.SYSIN DD *                                                       VTH00050
      INTEGER*2 IN(16)                                                  VTH00060
C      ARRAY 'IN' IS USED IN READING DATA FROM TAPE                     VTH00070
      REAL*4 XX(8192),YY(8192),ZZ(8192)                                 VTH00080
C      THE ABOVE REAL*4 ARRAYS ARE USED TO ORDER INPUT DATA AND         VTH00090
C      INITIALLY REPRESENT VOLTAGE - TIME SERIES INFORMATION.           VTH00100
      DIMENSION ZZX1(65536),ZZY1(65536),ZZV1(65536)                     VTH00110
      DIMENSION TIME2(65536)                                            VTH00120
      INTEGER K,Q,I5                                                    VTH00130
      REAL SUMX,SUMY,SUMZ,SUMT,AVE1,AVE2,AVE3,AVE4                      VTH00140
      INTEGER*4 ITB(12)/12*0/                                           VTH00150
      REAL*4    RTB(28)/28*0.0/                                         VTH00160
      REAL ALAB(4)/'CH-X','CH-Y','CH-Z','TOT'/                          VTH00170
      REAL*8 TITLE(12)                                                  VTH00180
      EQUIVALENCE(TITLE(1),RTB(5))                                      VTH00190
C      ARRAYS 'ITB','RTB','ALAB',AND 'TITLE' ARE USED IN GENERATING     VTH00200
C      THE VERTSATEC PLOTTER OUTPUT.                                    VTH00210
      DATA XX,YY/16384*0./                                              VTH00220
      DATA ZZ/8192*0./                                                  VTH00230
      K=0                                                               VTH00240
      I5=1                                                              VTH00250
      SUMX=0.0                                                          VTH00260
      SUMY=0.0                                                          VTH00270
      SUMZ=0.0                                                          VTH00280
      DO 31  IN1=1,65536                                                VTH00290
      ZZX1(IN1)=0.0                                                     VTH00300
      ZZY1(IN1)=0.0                                                     VTH00310
      ZZV1(IN1)=0.0                                                     VTH00320
      TIME2(IN1)=0.0                                                    VTH00330
   31 CONTINUE                                                          VTH00340
C        THE NEXT FIVE LINES SERVE AS A TIME DELAY IN STARTING THE      VTH00350
C        DATA ANALYSIS                                                  VTH00360
      ISEC=60                                                           VTH00370
      ITL=ISEC*32                                                       VTH00380
      DO 55  JJ=1,ITL                                                   VTH00390
      CALL RD(20,IN,200,IREC,IRR)                                       VTH00400
   55 CONTINUE                                                          VTH00410
      IFRAME=8192                                                       VTH00420
      NR=8                                                              VTH00430
      FNR=FLOAT(NR)                                                     VTH00440
      DO 70 L1=1,NR                                                     VTH00450
C      THE DO LOOP ENDING WITH STATEMENT 70 ENABLES THE PROGRAM TO      VTH00460
C      PROCESS A LARGE AMOUNT OF DATA BY REPEATING THE PROCESS IN       VTH00470
C      BLOCKS.                                                          VTH00480
```

```
C        'NR' REPRESENTS THE NUMBER OF DATA SEQUENCES.                         VTH00490
C        1 SEQUENCE CURRENTLY EQUALS 8192 DATA POINTS FOR EACH CHANNEL         VTH00500
C        OR 256 SECONDS OF DATA.                                               VTH00510
C                                                                              VTH00520
C         THE DO LOOP ENDING WITH 60 READS THE DATA FROM THE PCM FRAME         VTH00530
C         STRIPS OUT THE SYNC CODE, AND SORTS OUT THE DATA BY COIL             VTH00540
C         CHANNEL                                                              VTH00550
      DO 60 JJ=1,IFRAME                                                        VTH00560
      CALL RD(20,IN,1000,IREC,IRR)                                             VTH00570
      XX(JJ)=IN(2)                                                             VTH00580
      YY(JJ)=IN(3)                                                             VTH00590
      ZZ(JJ)=IN(4)                                                             VTH00600
   60 CONTINUE                                                                 VTH00610
      N=8192                                                                   VTH00620
      FN=FLOAT(N)                                                              VTH00630
      DELTAT=1./32.                                                            VTH00640
      DO 20 J=1,N                                                              VTH00650
      XX(J)=(XX(J)-1966.)*5./1966.                                             VTH00660
      YY(J)=(YY(J)-2085.)*5./2085.                                             VTH00670
      ZZ(J)=(ZZ(J)-2539.)*5./2539.                                             VTH00680
C        'XX' IS THE X-COIL DATA, 'YY' IS THE Y-COIL DATA,                     VTH00690
C        'ZZ' IS THE Z-COIL DATA                                               VTH00700
C       NORTH-SOUTH COMPONENT (XX) AND THE VERTICAL COMPONENT (ZZ)             VTH00710
   20 CONTINUE                                                                 VTH00720
      DO 91 I3=1,8192                                                          VTH00730
      ZZX1(I5)=XX(I3)                                                          VTH00740
      ZZY1(I5)=YY(I3)                                                          VTH00750
      ZZV1(I5)=ZZ(I3)                                                          VTH00760
      TIME2(I5)=(DELTAT*FLOAT(I3))+(256.0*FLOAT(K))                            VTH00770
      I5=I5+1                                                                  VTH00780
   91 CONTINUE                                                                 VTH00790
      K=K+1                                                                    VTH00800
   70 CONTINUE                                                                 VTH00810
C     DOUBLE RUNNING POINT AVERAGE                                             VTH00820
      DO 73 L2=1,2                                                             VTH00830
      Q=0                                                                      VTH00840
      DO 74 IS=1,65318                                                         VTH00850
      SUMX=0.0                                                                 VTH00860
      SUMY=0.0                                                                 VTH00870
      SUMZ=0.0                                                                 VTH00880
      DO 75 J=1,144                                                            VTH00890
      SUMX=ZZX1(Q+J)+SUMX                                                      VTH00900
      SUMY=ZZY1(Q+J)+SUMY                                                      VTH00910
      SUMZ=ZZV1(Q+J)+SUMZ                                                      VTH00920
   75 CONTINUE                                                                 VTH00930
      ZZX1(IS)=SUMX/144.                                                       VTH00940
      ZZY1(IS)=SUMY/144.                                                       VTH00950
      ZZV1(IS)=SUMZ/144.                                                       VTH00960
```

```
      Q=Q+1                                                             VTH00970
   74 CONTINUE                                                          VTH00980
   73 CONTINUE                                                          VTH00990
C                                                                       VTH01000
C    VERSATEC PLOT OF V - TIME SERIES VOLTAGE SMOOTHED                  VTH01010
C                                                                       VTH01020
      NPTS=2041./DELTAT +1.                                             VTH01030
C       'NPTS' DETERMINES NUMBER OF POINTS NECESSARY IN ORDER FOR       VTH01040
C        THE 0 TO 2041  SECS RANGE TO BE PLOTTED.                       VTH01050
C       FOR THE FOLLOWING 'ITB' AND 'RTB' VALUES REVIEW THE WRITE-UP    VTH01060
C       FOR THE SUBROUTINE PROCEDURE 'DRAWP'.                           VTH01070
      ITB(3)=20                                                         VTH01080
      ITB(4)=8                                                          VTH01090
      ITB(7)=1                                                          VTH01100
      ITB(12)=0                                                         VTH01110
      RTB(1)=0.0                                                        VTH01120
      RTB(2)=0.0                                                        VTH01130
      RTB(3)=ALAB(1)                                                    VTH01140
      READ(5,3000)TITLE                                                 VTH01150
      CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)                               VTH01160
      RTB(3)=ALAB(2)                                                    VTH01170
      READ(5,3000)TITLE                                                 VTH01180
      CALL DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)                               VTH01190
      RTB(3)=ALAB(3)                                                    VTH01200
      READ(5,3000)TITLE                                                 VTH01210
      CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)                               VTH01220
      ITB(3)=7                                                          VTH01230
      ITB(4)=5                                                          VTH01240
      ITB(12)=0                                                         VTH01250
      RTB(3)=ALAB(1)                                                    VTH01260
      READ(5,3000)TITLE                                                 VTH01270
      CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)                               VTH01280
      RTB(3)=ALAB(2)                                                    VTH01290
      READ(5,3000)TITLE                                                 VTH01300
      CALL DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)                               VTH01310
      RTB(3)=ALAB(3)                                                    VTH01320
      READ(5,3000)TITLE                                                 VTH01330
      CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)                               VTH01340
 3000 FORMAT(6A8)                                                       VTH01350
      STOP                                                              VTH01360
      END                                                               VTH01370
/*                                                                      VTH01380
//GO.SYSIN DD *                                                         VTH01390
LA MESA VILLAGE, 17 AUG 82, 1302-1336 LOCAL                             VTH01400
X COIL AMP IN VOLTS                                                     VTH01410
LA MESA VILLAGE, 17 AUG 82, 1302-1336 LOCAL                             VTH01420
Y COIL AMP IN VOLTS                                                     VTH01430
LA MESA VILLAGE, 17 AUG 82, 1302-1336 LOCAL                             VTH01440
```

```
Z COIL AMP  IN VOLTS                                                    VTH01450
LA MESA VILLAGE, 17 AUG 82, 1302-1336 LOCAL                             VTH01460
X COIL AMP  IN VOLTS                                                    VTH01470
LA MESA VILLAGE, 17 AUG 82, 1302-1336 LOCAL                             VTH01480
Y COIL AMP  IN VOLTS                                                    VTH01490
LA MESA VILLAGE, 17 AUG 82, 1302-1336 LOCAL                             VTH01500
Z COIL AMP  IN VOLTS                                                    VTH01510
/*                                                                      VTH01520
//GO.FT20F001 DD UNIT=3400-4,VOL=SER=GMDT3A,DISP=(OLD,KEEP),            VTH01530
//             LABEL=(1,NL,,IN),                                        VTH01540
//             DCB=(RECFM=FB,LRECL=32,BLKSIZE=512,DEN=2)                VTH01550
//GO.SYSDUMP DD SYSOUT=A                                                VTH01560
/*                                                                      VTH01570
//                                                                      VTH01580
```

APPENDIX C

LFVTC1 COMPUTER PROGRAM

Appendix C contains the LFVTC1 computer program that provides smoothed time series magnetic field plots. LFVTC1 uses the subroutine RD to strip voltage data off digital tapes. The voltage data is normalized to ± 5V. The voltage data is fast fourier transformed using the FOURT subroutine. The transfer function is applied and forward transform taken. The resulting magnetic field data undergoes a double 144 point running average and is plotted using the DRAWP subroutine.

```
//LFVT$1L JOB (1029,0129),'STEVENS    SMC 2670',CLASS=G                 MAG00010
//*MAIN ORG=NPGVM1.1029P,LINES=(65)                                     MAG00020
//*FORMAT PR,DDNAME=PLOT.SYSVECTR,DEST=LOCAL                            MAG00030
// EXEC FRTXCLGP,PARM.LKED='LIST,MAP,XREF',REGION.GO=2048K              MAG00040
//FORT.SYSIN DD *                                                       MAG00050
      INTEGER*2 IN(16)                                                  MAG00060
C       ARRAY 'IN' IS USED IN READING DATA FROM TAPE                    MAG00070
      COMPLEX*8 XX(8192),YY(8192),ZZ(8192),TF(8192)                     MAG00080
C       THE ABOVE COMPLEX*8 ARRAYS ARE USED TO ORDER INPUT DATA AND     MAG00090
C       INITIALLY REPRESENT VOLTAGE - TIME SERIES INFORMATION.          MAG00100
      DIMENSION TIME(8192),FREQ(8192),WORK(16384),FRQ2(8192)            MAG00110
      DIMENSION ZX1(8192),ZY1(8192),ZV1(8192),ZT1(8192)                 MAG00120
      DIMENSION ZZX1(65536),ZZY1(65536),ZZV1(65536)                     MAG00130
      DIMENSION ZZT1(65536),TIME2(65536)                                MAG00140
C       THE 'Z' ARRAYS REPRESENT FREQUENCY DOMAIN (FF TRANSFORMED)      MAG00150
C       MAGNITUDE DATA AND ARE EVENTUALLY CONVERTED TO POWER SPECTRAL   MAG00160
C       DENSITY INFORMATION. ZX1,ZY1,ZV1,AND ZT1 REPRESENT MAGNITUDE    MAG00170
C       VALUES.                                                         MAG00180
      INTEGER K,I4,I5,Q                                                 MAG00190
      REAL SUMX,SUMY,SUMZ,SUMT,AVE1,AVE2,AVE3,AVE4                      MAG00200
      REAL CONSTX,CONSTY,CONSTZ,CONSTT                                  MAG00210
      INTEGER*4 ITB(12)/12*0/                                           MAG00220
      REAL*4    RTB(28)/28*0.0/                                         MAG00230
      REAL ALAB(4)/'CH-X','CH-Y','CH-Z','TOT'/                          MAG00240
      REAL*8 TITLE(12)                                                  MAG00250
      EQUIVALENCE(TITLE(1),RTB(5))                                      MAG00260
C       ARRAYS 'ITB','RTB','ALAB',AND 'TITLE' ARE USED IN GENERATING    MAG00270
C       THE VERTSATEC PLOTTER OUTPUT.                                   MAG00280
      DATA XX,YY/16384*(0.,0.)/                                         MAG00290
      DATA ZZ,TF/16384*(0.,0.)/                                         MAG00300
      DATA ZX1,ZY1/16384*0./                                            MAG00310
      DATA ZV1,ZT1/16384*0./                                            MAG00320
      DATA TIME,FREQ/16384*0./                                          MAG00330
      K=0                                                               MAG00340
      I4=1                                                              MAG00350
      I5=1                                                              MAG00360
      CONSTX=0.0                                                        MAG00370
      CONSTY=0.0                                                        MAG00380
      CONSTZ=0.0                                                        MAG00390
      CONSTT=0.0                                                        MAG00400
      SUMX=0.0                                                          MAG00410
      SUMY=0.0                                                          MAG00420
      SUMZ=0.0                                                          MAG00430
      SUMT=0.0                                                          MAG00440
      AVE1=0.0                                                          MAG00450
      AVE2=0.0                                                          MAG00460
      AVE3=0.0                                                          MAG00470
      AVE4=0.0                                                          MAG00480
```

```
      TWOPI=6.2831853                                                   MAG00490
      COS60=COS(TWOPI/6.)                                               MAG00500
      COS30=COS(TWOPI/12.)                                              MAG00510
      D=16.75*TWOPI/360.                                                MAG00520
      COSD=COS(D)                                                       MAG00530
      COSD1=COS((90. - D)*TWOPI/360.)                                   MAG00540
C       D IS THE DECLINATION OR MAGNETIC VARIATION AT THE MAGNETOMETER  MAG00550
C       SITE.                                                           MAG00560
      DO 31  IN1=1,65536                                                MAG00570
      ZZX1(IN1)=0.0                                                     MAG00580
      ZZY1(IN1)=0.0                                                     MAG00590
      ZZV1(IN1)=0.0                                                     MAG00600
      ZZT1(IN1)=0.0                                                     MAG00610
      TIME2(IN1)=0.0                                                    MAG00620
   31 CONTINUE                                                          MAG00630
C       THE NEXT FIVE LINES SERVE AS A TIME DELAY IN STARTING THE       MAG00640
C       DATA ANALYSIS                                                   MAG00650
      ISEC=60                                                           MAG00660
      ITL=ISEC*32                                                       MAG00670
      DO 55  JJ=1,ITL                                                   MAG00680
      CALL  RD(20,IN,200,IREC,IRR)                                      MAG00690
   55 CONTINUE                                                          MAG00700
      IFRAME=8192                                                       MAG00710
      NR=8                                                              MAG00720
      FNR=FLOAT(NR)                                                     MAG00730
      DO 70  L1=1,NR                                                    MAG00740
C      THE DO LOOP ENDING WITH STATEMENT 70 ENABLES THE PROGRAM TO      MAG00750
C      PROCESS A LARGE AMOUNT OF DATA BY REPEATING THE PROCESS IN       MAG00760
C      BLOCKS.                                                          MAG00770
C      'NR' REPRESENTS THE NUMBER OF DATA SEQUENCES TO BE AVERAGED.     MAG00780
C      1 SEQUENCE CURRENTLY EQUALS 8192 DATA POINTS FOR EACH CHANNEL    MAG00790
C      OR 256 SECONDS OF DATA.                                          MAG00800
C                                                                       MAG00810
C       THE DO LOOP ENDING WITH 60 READS THE DATA FROM THE PCM FRAME    MAG00820
C       STRIPS OUT THE SYNC CODE, AND SORTS OUT THE DATA BY COIL        MAG00830
C       CHANNEL                                                         MAG00840
      DO 60  JJ=1,IFRAME                                                MAG00850
      CALL  RD(20,IN,1000,IREC,IRR)                                     MAG00860
      XX(JJ)=IN(2)                                                      MAG00870
      YY(JJ)=IN(3)                                                      MAG00880
      ZZ(JJ)=IN(4)                                                      MAG00890
   60 CONTINUE                                                          MAG00900
C       THE FOLLOWING SECTION GENERATES THE TIME AND FREQUENCY          MAG00910
C       ARRAYS AND NORMALIZES THE INPUT PCM DATA TO VOLTAGE FORM        MAG00920
C       IN PREPARATION FOR FAST FOURIER TRANSFORM TO THE FREQUENCY      MAG00930
C       DOMAIN.                                                         MAG00940
      N=8192                                                            MAG00950
      FN=FLOAT(N)                                                       MAG00960
```

```
      DELTAT=1./32.                                                     MAG00970
      DELTAF=1./(FN*DELTAT)                                             MAG00980
      DO 20 J=1,N                                                       MAG00990
      TIME(J)=DELTAT*FLOAT(J)                                           MAG01000
      FREQ(J)=DELTAF*FLOAT(J)                                           MAG01010
      XX(J)=(XX(J)-1966.)*5./1966.                                      MAG01020
      XX(J)=REAL(XX(J))                                                 MAG01030
      YY(J)=(YY(J)-2085.)*5./2085.                                      MAG01040
      YY(J)=REAL(YY(J))                                                 MAG01050
      ZZ(J)=(ZZ(J)-2539.)*5./2539.                                      MAG01060
      ZZ(J)=REAL(ZZ(J))                                                 MAG01070
C       'XX' IS THE X-COIL DATA, 'YY' IS THE Y-COIL DATA,               MAG01080
C       'ZZ' IS THE Z-COIL DATA, AND 'TF' IS THE PROJECTION OF THE      MAG01090
C        NORTH-SOUTH COMPONENT (XX) AND THE VERTICAL COMPONENT (ZZ)     MAG01100
C        ON THE TOTAL GEOMAGNETIC FIELD VECTOR.                         MAG01110
   20 CONTINUE                                                          MAG01120
      DO 21 J=1,N                                                       MAG01130
      FRQ2(J)=ALOG10(FREQ(J))                                           MAG01140
   21 CONTINUE                                                          MAG01150
C        THE NEXT FOUR STATEMENTS PERFORM AN FFT ON THE INPUT           MAG01160
C        TIME SERIES DATA. SEE THE WRITEUP ON 'FOURT' FOR               MAG01170
C        FURTHER INFORMATION.                                           MAG01180
      CALL FOURT(XX,N,1,-1,0,WORK)                                      MAG01190
      CALL FOURT(YY,N,1,-1,0,WORK)                                      MAG01200
      CALL FOURT(ZZ,N,1,-1,0,WORK)                                      MAG01210
C      THE NEXT BLOCK OF STATEMENTS APPLY THE SYSTEM (VOLTAGE TO        MAG01220
C      B-FIELD) TRANSFER FUNCTION TO THE TRANSFORMED FREQUENCY          MAG01230
C      DOMAIN DATA.  THIS BLOCK ENDS AT STATEMENT 9.                    MAG01240
C      THE TRANSFER FUNCTION CONVERTS VOLTS TO NANOTESLAS (GAMMAS).     MAG01250
C      ***WARNING*** THIS TRANSFER FUNCTIONS YIELDS AN INACCURATE       MAG01260
C      PHASE.  USE A DIFFERENT TRANSFER FUNCTION IF PHASE INFORMATION   MAG01270
C      NEEDED.                                                          MAG01280
      DO 9 L=1,N                                                        MAG01290
      FRQ=FREQ(L)                                                       MAG01300
      IF(FRQ.LE.25.)GO TO 1                                             MAG01310
      XX(L)=XX(L)/28.                                                   MAG01320
      GO TO 8                                                           MAG01330
    1 IF(FRQ.LE.15.)GO TO 2                                             MAG01340
      XX(L)=XX(L)/(105.5-3.14*FRQ)                                      MAG01350
      YY(L)=YY(L)/(181.32-7.588*FRQ)                                    MAG01360
      ZZ(L)=ZZ(L)/(177.26-7.484*FRQ)                                    MAG01370
      GO TO 8                                                           MAG01380
    2 IF(FRQ.LE.10.)GO TO 3                                             MAG01390
      XX(L)=XX(L)/(5.958*FRQ-30.97)                                     MAG01400
      YY(L)=YY(L)/(7.166*FRQ-39.99)                                     MAG01410
      ZZ(L)=ZZ(L)/(6.49*FRQ-32.35)                                      MAG01420
      GO TO 8                                                           MAG01430
    3 IF(FRQ.LE.7.5)GO TO 4                                             MAG01440
```

```
      XX(L)=XX(L)/(3.492*FRQ-6.31)                                      MAG01450
      YY(L)=YY(L)/(4.252*FRQ-10.85)                                     MAG01460
      ZZ(L)=ZZ(L)/(4.044*FRQ-7.89)                                      MAG01470
      GO TO 8                                                           MAG01480
    4 IF(FRQ.LE.5.)GO TO 5                                              MAG01490
      XX(L)=XX(L)/(2.6311*FRQ+0.14667)                                  MAG01500
      YY(L)=YY(L)/(3.012*FRQ-1.55)                                      MAG01510
      ZZ(L)=ZZ(L)/(3.184*FRQ-1.44)                                      MAG01520
      GC TO 8                                                           MAG01530
    5 IF(FRQ.LE.3.)GO TO 6                                              MAG01540
      XX(L)=XX(L)/(2.6311*FRQ+0.14667)                                  MAG01550
    7 YY(L)=YY(L)/(2.702*FRQ)                                           MAG01560
      ZZ(L)=ZZ(L)/(2.92*FRQ)                                            MAG01570
      GO TO 8                                                           MAG01580
    6 XX(L)=XX(L)/(2.72*FRQ)                                            MAG01590
      GO TO 7                                                           MAG01600
    8 CCNTINUE                                                          MAG01610
      TF(L)=(XX(L)*COSD + YY(L)*COSD1)*COS60 + ZZ(L)*COS30              MAG01620
    9 CCNTINUE                                                          MAG01630
      CALL FCURT(XX,N,1,1,1,WORK)                                       MAG01640
      CALL FOURT(YY,N,1,1,1,WORK)                                       MAG01650
      CALL FOURT(ZZ,N,1,1,1,WORK)                                       MAG01660
      CALL FOURT(TF,N,1,1,1,WORK)                                       MAG01670
      DO 57 J=1,N                                                       MAG01680
      XX(J)=XX(J)/FN                                                    MAG01690
      YY(J)=YY(J)/FN                                                    MAG01700
      ZZ(J)=ZZ(J)/FN                                                    MAG01710
      TF(J)=TF(J)/FN                                                    MAG01720
   57 CONTINUE                                                          MAG01730
      DO 56 I3=1,N                                                      MAG01740
      ZX1(I3)=CABS(XX(I3))                                              MAG01750
      ZY1(I3)=CABS(YY(I3))                                              MAG01760
      ZV1(I3)=CABS(ZZ(I3))                                              MAG01770
      ZT1(I3)=CABS(TF(I3))                                              MAG01780
   56 CCNTINUE                                                          MAG01790
C     THE NEXT 44 LINES OF CODE CORRECT DATA BLOCK END JUMPS.           MAG01800
      IF(K.NE.0) GO TO 36                                               MAG01810
      DO 66 IS=8048,8192                                                MAG01820
      SUMX=ZX1(IS)+SUMX                                                 MAG01830
      SUMY=ZY1(IS)+SUMY                                                 MAG01840
      SUMZ=ZV1(IS)+SUMZ                                                 MAG01850
      SUMT=ZT1(IS)+SUMT                                                 MAG01860
   66 CCNTINUE                                                          MAG01870
      CCNSTX=SUMX/144.                                                  MAG01880
      CONSTY=SUMY/144.                                                  MAG01890
      CONSTZ=SUMZ/144.                                                  MAG01900
      CCNSTT=SUMT/144.                                                  MAG01910
      DO 67 IS=1,8192                                                   MAG01920
```

```
      ZZX1(I4)=ZX1(IS)                                                  MAG01930
      ZZY1(I4)=ZY1(IS)                                                  MAG01940
      ZZV1(I4)=ZV1(IS)                                                  MAG01950
      ZZT1(I4)=ZT1(IS)                                                  MAG01960
      I4=I4+1                                                           MAG01970
   67 CONTINUE                                                          MAG01980
      GO TO 37                                                          MAG01990
   36 CONTINUE                                                          MAG02000
      SUMX=0.0                                                          MAG02010
      SUMY=0.0                                                          MAG02020
      SUMZ=0.0                                                          MAG02030
      SUMT=0.0                                                          MAG02040
      DO 68  IS=1,144                                                   MAG02050
      SUMX=ZX1(IS)+SUMX                                                 MAG02060
      SUMY=ZY1(IS)+SUMY                                                 MAG02070
      SUMZ=ZV1(IS)+SUMZ                                                 MAG02080
      SUMT=ZT1(IS)+SUMT                                                 MAG02090
   68 CONTINUE                                                          MAG02100
      AVE1=SUMX/144.                                                    MAG02110
      AVE2=SUMY/144.                                                    MAG02120
      AVE3=SUMZ/144.                                                    MAG02130
      AVE4=SUMT/144.                                                    MAG02140
      DO 69  IS=1,8192                                                  MAG02150
      ZZX1(I4)=ZX1(IS)+(CONSTX-AVE1)                                    MAG02160
      ZZY1(I4)=ZY1(IS)+(CONSTY-AVE2)                                    MAG02170
      ZZV1(I4)=ZV1(IS)+(CONSTZ-AVE3)                                    MAG02180
      ZZT1(I4)=ZT1(IS)+(CONSTT-AVE4)                                    MAG02190
      I4=I4+1                                                           MAG02200
   69 CONTINUE                                                          MAG02210
   37 CONTINUE                                                          MAG02220
      DO 91  I3=1,8192                                                  MAG02230
      TIME2(I5)=(DELTAT*FLOAT(I3))+(256.0*FLOAT(K))                     MAG02240
      I5=I5+1                                                           MAG02250
   91 CONTINUE                                                          MAG02260
      K=K+1                                                             MAG02270
   70 CONTINUE                                                          MAG02280
C     THE FOLLOWING LINES OF CODE PERFORMS A DOUBLE RUNNING POINT       MAG02290
C     AVERAGE ON THE DATA.                                              MAG02300
      DO 73  L2=1,2                                                     MAG02310
      Q=0                                                               MAG02320
      DO 74  IS=1,65318                                                 MAG02330
      SUMX=0.0                                                          MAG02340
      SUMY=0.0                                                          MAG02350
      SUMZ=0.0                                                          MAG02360
      SUMT=0.0                                                          MAG02370
      DO 75  J=1,144                                                    MAG02380
      SUMX=ZZX1(Q+J)+SUMX                                               MAG02390
      SUMY=ZZY1(Q+J)+SUMY                                               MAG02400
```

```
      SUMZ=ZZV1(Q+J)+SUMZ                                               MAGO2410
      SUMT=ZZT1(Q+J)+SUMT                                               MAGO2420
   75 CONTINUE                                                          MAGO2430
      ZZX1(IS)=SUMX/144.                                                MAGO2440
      ZZY1(IS)=SUMY/144.                                                MAGO2450
      ZZV1(IS)=SUMZ/144.                                                MAGO2460
      ZZT1(IS)=SUMT/144.                                                MAGO2470
      Q=Q+1                                                             MAGO2480
   74 CONTINUE                                                          MAGO2490
   73 CONTINUE                                                          MAGO2500
C                                                                       MAGO2510
C     VERSATEC PLOT OF B - MAGNETIC FIELD (SMOOTHED)                    MAGO2520
C                                                                       MAGO2530
      NPTS=2041./DELTAT +1.                                             MAGO2540
C       'NPTS' DETERMINES NUMBER OF POINTS NECESSARY IN ORDER FOR       MAGO2550
C        THE 0 TO 2041  SECS RANGE TO BE PLOTTED.                       MAGO2560
C       FOR THE FOLLOWING 'ITB' AND 'RTB' VALUES REVIEW THE WRITE-UP    MAGO2570
C       FOR THE SUBROUTINE PROCEDURE 'DRAWP'.                           MAGO2580
      ITB(3)=20                                                         MAGO2590
      ITB(4)=8                                                          MAGO2600
      ITB(7)=1                                                          MAGO2610
      ITB(12)=0                                                         MAGO2620
      RTB(1)=0.0                                                        MAGO2630
      RTB(2)=0.0                                                        MAGO2640
      RTB(3)=ALAB(1)                                                    MAGO2650
      READ(5,3000)TITLE                                                 MAGO2660
      CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)                               MAGO2670
      RTB(3)=ALAB(2)                                                    MAGO2680
      READ(5,3000)TITLE                                                 MAGO2690
      CALL DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)                               MAGO2700
      RTB(3)=ALAB(3)                                                    MAGO2710
      READ(5,3000)TITLE                                                 MAGO2720
      CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)                               MAGO2730
      ITB(12)=1                                                         MAGO2740
      RTB(3)=ALAB(4)                                                    MAGO2750
      READ(5,3000)TITLE                                                 MAGO2760
      CALL DRAWP(NPTS,TIME2,ZZT1,ITB,RTB)                               MAGO2770
      ITB(3)=7                                                          MAGO2780
      ITB(4)=5                                                          MAGO2790
      ITB(12)=0                                                         MAGO2800
      RTB(3)=ALAB(1)                                                    MAGO2810
      READ(5,3000)TITLE                                                 MAGO2820
      CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)                               MAGO2830
      RTB(3)=ALAB(2)                                                    MAGO2840
      READ(5,3000)TITLE                                                 MAGO2850
      CALL DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)                               MAGO2860
      RTB(3)=ALAB(3)                                                    MAGO2870
      READ(5,3000)TITLE                                                 MAGO2880
```

```
      CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)                               MAG02890
      ITB(12)=1                                                         MAG02900
      RTB(3)=ALAB(4)                                                    MAG02910
      READ(5,3000)TITLE                                                 MAG02920
      CALL DRAWP(NPTS,TIME2,ZZT1,ITB,RTB)                               MAG02930
 3000 FORMAT(6A8)                                                       MAG02940
      STOP                                                              MAG02950
      END                                                               MAG02960
/*                                                                      MAG02970
//GO.SYSIN DD *                                                         MAG02980
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL                             MAG02990
X COIL AMP IN NT                                                        MAG03000
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL                             MAG03010
Y COIL AMP IN NT                                                        MAG03020
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL                             MAG03030
Z COIL AMP IN NT                                                        MAG03040
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL                             MAG03050
TOTAL FIELD  AMP IN NT                                                  MAG03060
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL                             MAG03070
X COIL AMP IN NT                                                        MAG03080
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL                             MAG03090
Y COIL AMP IN NT                                                        MAG03100
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL                             MAG03110
Z COIL AMP IN NT                                                        MAG03120
LA MESA VILLAGE, 17 AUG 82, 1825-1859 LOCAL                             MAG03130
TOTAL FIELD AMP IN NT                                                   MAG03140
/*                                                                      MAG03150
//GO.FT20F001 DD UNIT=3400-4,VOL=SER=GMDT21,DISP=(OLD,KEEP),            MAG03160
//             LABEL=(1,NL,,IN),                                        MAG03170
//             DCB=(RECFM=FB,LRECL=32,BLKSIZE=512,DEN=2)                MAG03180
//GO.SYSDUMP DD SYSOUT=A                                                MAG03190
/*                                                                      MAG03200
//                                                                      MAG03210
```

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